Proceedings of the Workshop on Habitat Improvements, Whistler, B.C., 8-10 May 1984

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by

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ABSTRACT

Patterson, John H. (Editor). 1986. Proceedings of the Workshop on Habitat Improvements, Whistler, British Columbia. 8-10 May, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1483: 219 p.

The workshop on salmonid habitat improvements provided information on a variety of improvement activities, techniques and concepts for a wide range of aquatic habitats (estuaries, lakes, streams and rivers). The presentations from a broad spectrum of professions (federal and provincial biologists, consulting biologists and engineers, economists, research scientists) representing Ontario, British Columbia, Washington and Oregon, addressed "state of the art" techniques and presented results from projects designed to restore and develop habitats. Participants described techniques that worked, and in some cases outlined how habitat manipulations affected fish production. In addition to valuable information about improvement techniques, the workshop produced a number of clear statements and conclusions from several speakers. These conclusions included the following:

- estuaries have received less study than freshwater habitats (and are therefore not as well understood);
- the research link is essential to understanding the relationship between habitat type and fish production. We must understand what we are doing in manipulating habitat and why it works;
- we have a strong obligation to evaluate improvement projects;
- improvement activities should be tied to a cooperatively developed production plan (district or watershed basis) and specific management strategies;
- individual projects should be part of the larger (holistic watershed) picture, as activities upland, on stream banks and upstream may affect project design and effectiveness and should be considered in project development;
- communication within departments, between colleagues, agencies, provinces and states is essential both in the planning of improvement projects as well as in reporting results of project assessments.

The workshop closed with a plea to "keep in touch" through cooperative projects, workshops and information exchange; and through the use of the American Fisheries Society publication, "Fisheries." In addition it was recommended that a workshop on the evaluation of enhancement and restoration activities be conducted in the very near future.

RÉSUMÉ

Patterson, John H. (Editor). 1986. Proceedings of the Workshop on Habitat Improvements, Whistler, British Columbia. 8-10 May, 1984. Can. Tech. Rep. Fish. Aquat. Sci. 1483: 219 p.

L'atelier sur les améliorations de l'habitat des salmonidés a permis de fournir des informations sur diverses activités, techniques et notions liées à l'amélioration pour une grande variété d'habitats aquatiques (estuaires, lacs, ruisseaux et rivières). Dans les exposés faits par une vaste gamme de professionnels (biologistes fédéraux et provinciaux, biologistes et ingénieurs conseils, économistes, chercheurs scientifiques) représentant l'Ontario, la Colombie-Britannique, les états de Washington et de l'Oregon, ces derniers ont abordé les techniques de pointe et ont présenté les résultats de projets conçus pour rétablir et mettre en valeur les habitats. Les participants ont décrit des techniques qui ont bien fonctionné et, dans certains cas, ont indiqué de quelle façon les manipulations de l'habitat ont affecté la production de poissons. En plus des informations utiles sur les techniques d'amélioration, l'atelier a suscité un certain nombre d'énoncés et de conclusions claires livrés par plusieurs conférenciers. Voici quelques-unes de ces conclusions:

- les estuaires ont été moins étudiés que les habitats d'eaux douces (et par conséquent on ne les comprend pas aussi bien);

- la liaison avec la recherche est essentielle pour comprendre la relation entre le type d'habitat et la production de poisson. Nous devons comprendre ce que nous faisons lorsque nous manipulons l'habitat et pourquoi cela marche;

- nous avons une grande obligation d'évaluer les projets d'amélioration;

- les activités d'amélioration doivent être liées à un plan de production établi en collaboration (suivant le district ou le bassin versant) et à des stratégies particulières de gestion;

- les projets individuels doivent faire partie du tableau plus large (bassin versant holistique), étant donné que les activités sur les hautes terres, sur les berges des cours d'eau et en amont peuvent modifier la conception et l'efficacité des projets et que l'on doit en tenir compte dans l'élaboration des projets;

- la communication au sein des ministères, entre les collègues, les organismes, les provinces et les états est essentielle aussi bien pour la planification des projets d'amélioration que pour communiquer les résultats des évaluations de projets.

L'atelier s'est terminé par une incitation "à rester en contact" par le biais de projets réalisés en collaboration, d'ateliers et d'échanges d'informations ainsi que par le truchement de la publication de la Société américaine des pêches intitulée "Fisheries." En outre, on a recommandé qu'un atelier sur l'évaluation des activités de remise en état et de mise en valeur ait lieu dans un avenir très rapproché.

WORKSHOP INTRODUCTION

J.H. Patterson & T.D. Bird
Habitat Management Division, DFO

John H. Patterson: We have a very interesting agenda and some very interesting speakers from within B.C., both the Department of Fisheries and the Ministry of Environment, from Ontario, and from Washington and Oregon states.

The agenda covers all ecosystems, from the overall watershed considerations to the small stream, lake and river habitat improvement prescriptions, including estuarine habitats. This workshop covers the aquatic systems that fish and invertebrates utilize, the underlying substrates, riparian vegetation, and the upland water quantity and quality concerns.

The workshop emphasizes salmonids which make up approximately 75 percent of the landed value of fish in the province.

The focus is on the rearing, spawning, and estuarine life stages of the salmonids in B.C. Certainly, other marine species and invertebrates are important aspects of the Department's mandate and should be also given consideration in habitat improvement efforts; however, we will be concentrating on salmonids during this workshop.

Throughout the workshop, I hope that the participants and guests have an opportunity to talk with all groups within the Department, notably our habitat representatives, our salmonid enhancement people, and quite a large contingent of research people from the Nanaimo and West Vancouver research facilities.

Art Tautz (Provincial Ministry of Environment) is also here from the Fisheries Branch, and is a representative of the provincial side of the Salmonid Enhancement Program.

Habitat improvement, as it pertains to this workshop, incorporates enhancement, rehabilitation, restoration, improvement and development of fish habitats. Projects are directed towards the restoration of degraded or lost habitats, the improvement of rearing and spawning habitats in streams and estuaries, and the development of underutilized habitats, or the creation of new areas for fish and invertebrate populations.

Due to time considerations, the organizers of the workshop felt that we would not reemphasize some of the conventional enhancement techniques, such as stream clearance, obstruction removal, fishway construction, and flow control, although they are certainly pertinent aspects of the whole picture in British Columbia.

We hope to demonstrate some of the projects and techniques current in the Pacific Northwest. The intent of the workshop is to demonstrate a bit of the state of the art in the province by both the federal and provincial governments, and to have input from our colleagues in the United States and Ontario to demonstrate some directions we might go in the future.

Now, I'll ask Tom Bird, associate head of the Habitat Management Division of the Department of Fisheries, to make a few remarks regarding habitat improvement in the Pacific region.

Tom D. Bird: Very briefly, the reason for this workshop, specifically with respect to the restoration, or improvement, as you wish to call it, began, as far as the Department's concerned, in 1981, in a program called "The Revitalization Program," which examined fish habitat management in the nation.

Basically, the revitalization project, started in the Pacific Region. In fact, it's continuing today. Pacific Region is looking at the organization of habitat, and one of the cornerstones of that project, and as indicated in the report, was the fact that restoration and development was one of the areas that habitat should really pursue. In fact, in that document, it said it's seen as one of the more effective strategies for eventually reversing the trend in habitat loss. The Department has been addressing the restoration of fish habitat through a variety of initiatives.

At the same time, and following that, there was a mention of it in the Pearse document (Turning the Tide, the Commission report on Pacific Fisheries Policy, Sept. 1982), the importance of restoration or improvement. As we sit, there is being formalized and finalized, a national fish habitat management policy paper that reflects the habitat management approach, goals, and objectives for DFO. It has a major section devoted to the importance of restoration which is one of the three goals in the paper, and as a strategy suggests that the Department restore the productive capacity of degraded habitats either through direct government action, or in cooperation with others.

The direction DFO has been going with respect to improvement projects didn't happen by accident. Pearse didn't mention restoration by accident. The revitalization people put it there for a reason; the national policy reflects it because a lot of people in the organization have been stressing the importance of it, and pushing it as a way of achieving some results.

In this workshop, we'll be looking at those elements which reflect a variety of activities whether it be restoration, development, or enhancement. This covers everything from public participation to research, and from concrete to clay, in other words, a broad spectrum.

I'm convinced that projects we undertake in the future will be more cooperative ventures among the various DFO elements.

Projects have traditionally been conducted by individual divisions or individual groups. We have to look at projects that involve cooperative efforts from every element of the organization whether it's SEP or management, or the core, or the area people, including the provincial government, and the private sector.

The private sector is one that obviously offers a great opportunity. We should pursue that element aggressively, as far as I'm concerned.

On another point: there's traditionally a tremendous amount of discussion about whether we should restore or improve habitat for its own sake. Many of us feel that these projects must in all cases be tied into production targets, have to be measurable, presumably should be manageable, and integrated in every way with management decisions. I think this is a very honorable objective, and obviously has to be pursued. We obviously have to integrate with management and the other elements in the sense of ensuring that the project fits.

However, with all due respect, to the management people, I would hate to see us wait until, for instance, we understood the entire contribution of habitat to all stocks. There are some suggestions that there are some difficulties managing some of the stocks in some of the areas, specifically.

In the meantime, presumably people involved in the restoration works, will continue to conduct the needed research. It will continue, and presumably we will continue to develop methods, projects, pilot works that will ultimately provide management with the habitat base for stock manageability.

But, in the meantime, I don't think we should lose sight of the fact that some of these projects, whether it be a Campbell River project, or a False Creek project, which may not immediately have obvious or measurable production benefits, can be show-pieces for the value of cooperation, and may, in some instances, outweigh production values in any case. I don't think we should lose sight of that.

Through this workshop, and future ones, we can come together and examine some of the better initiatives and opportunities before us.

SESSION I—ESTUARINE AND MARINE HABITAT IMPROVEMENTS

Introduction by:
Colin Levings
Fisheries Research Branch
West Vancouver Laboratory, DFO

I think it's kind of interesting that our first session of the day rotates around the estuarine and the marine environments, because, in reality, these particular habitats are the ones that have been studied least.

The history of hard data on estuaries is certainly behind that of the freshwater environment, but we are gradually building up a good body of knowledge through a variety of research people, for example, a group from the Nanaimo Biological Station. Some of the earlier work on the Squamish and Fraser estuaries, in the past ten years, has shown that wild salmonids especially are using estuaries.

Some of the facts that are important in how they use them are still being worked out. There's a number of factors which are thought to be important for estuaries, and they all interrelate to show that at least wild stocks of salmon are adapted to use estuaries.

These factors are often thought to be food production, predation, cover, and water quality aspects. The various species use the estuaries for differing lengths of time; to date we know, wild chinook and wild chum use the estuaries most extensively.

In certain estuaries, coho fry also show residency. Pink and sockeye tend to move through estuaries quite rapidly. Cutthroat trout, in some instances, spend a lot of their life in an estuary.

I think there's an interesting problem coming up with wild versus cultured fish in estuary improvement and estuary use. Some of the work that we've been doing has shown that the pattern of use of cultured fish from hatcheries is quite different from wild fish.

There are problems of design in restoration or improvement in estuaries, because of their relatively open systems. There's a matter of arranging appropriate reference habitats within an estuary or between an estuary. How do we set up a way of measuring recovery or restoration between estuaries, or within an estuary, because there's interaction between habitat types and within an estuary there's four or five habitats.

Finally, we recognize that there's habitat substitution rather than restoration in many instances. This is another issue that is gradually being worked out. There's still a long way to go on that one.

We have an obligation to evaluate our projects, although it's often very difficult to evaluate in terms of fish production. The history of some of the estuarine restoration work in other areas has shown that many of these projects have not gone on long enough. They've been pursued only for a couple of years, and then for funding or other reasons, they've just been dropped. We can't tolerate too many of those types of experiences. Because of the natural cycles that are out there, we have to have a decent length of time in order to evaluate projects properly.

When we get outside the estuary onto the foreshore beaches, there are fewer data points. We know that heavy concentrations of salmon migrate along certain marine beaches. We found this in places like Discovery Passage, where millions of chum and pink move along the beaches; this has been known for some time. Our information is very poor on some of the key habitats, such as these beaches and kelp beds. They are even more open systems than are estuaries, have more onshore-offshore movements and there's more smearing of habitat influences.

Embayments for non-salmonid fish in foreshore areas have been getting a lot of interest elsewhere, for example, in Washington state.

In B.C., there are some artifical reefs in place already, such as Roberts Bank. I understand it has yet to be evaluated. There also has been some pilot scale experiments in Barkley Sound with rockfish. Some of the things that haven't been looked at to date include sand/mud habitat improvement. I don't know if anybody has done a project like that with flounder and sole.

If you are working in contaminated areas, there's some possibility that some of these long-lived species may soak up some of these contaminants. That is something that should be considered, for example, in a place like False Creek, where there are various chemicals in the bottom substrate.

In these major areas, there has actually been a number of projects undertaken, starting in 1980.

There was a manuscript report produced on estuarine restoration. Rick Higgins (DFO, Nanaimo, B.C.) worked on a very small-scale project in Deas Slough about 1980 and 1981. There have been projects in the Fraser for pilot-scale plant transplants on dredged sand. There's been water quality improvements in places like Neroutsos Inlet. The Campbell River estuary is a more current transplant project, as is Englishman River estuary.

The Nanaimo River estuary will be discussed by Carey McAllister. More recent projects include the Cowichan estuary, Gundersen Slough, and Port Moody.

On foreshores, we've had in recent times the Roberts Bank compensation exercise, which has involved construction of a riprap quay to cut down on erosion, and subsequent colonization by kelp beds. There has been some research on eelgrass transplants. There was a Nanaimo eelgrass transplant and another in Gibson's Marina.

For nonsalmonids, there is a committee for hard substrate and kelp bed communities, an example where we're having direct interaction with a sports fishery; it's one that can be directly evaluated. As I said, there were some pilot-scale experiments in Barkley Sound. Herring spawn transplant is one that we haven't really thought about too much, but as some of you know, there are efforts going on to move herring spawn from one area to another; for example, at Hidden Basin on Nelson Island. Results are mixed, but I understand from the herring group that they're making another stab at it.

WATER QUALITY—THE FORGOTTEN RESTORATION ISSUE

Mike Nassichuk, Chief
Water Quality Unit
Habitat Management Division, DFO

INTRODUCTION

There are a number of reasons why water quality is not generally considered within the context of fish habitat restoration or improvement. In part, this has evolved from the traditional manner in which water quality issues have been addressed and aquatic pollution problems managed.

The federal Fisheries Act contains provisions designed to control the degradation of fisheries waters through preventing the discharge of substances that are deleterious to fish. In 1977, amendments to this Act resulted in additional provisions to protect fish habitat which is defined as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes". While this definition can be interpreted to include water quality requirements, it primarily pertains to the physical and biological characteristics of fish habitat. Thus, fish habitats are generally considered in terms of productive units that are utilized directly by fish or contribute to fish productivity such as estuarine and freshwater marshes, intertidal areas, stream bottoms, and riparian vegetation. Likewise, water availability as determined by such indices as stream depth, flow regime, and minimum flow, is a significant variable that is often directly linked to habitat restoration efforts.

LIQUID VERSUS SOLID HABITAT

Certain technical considerations and difficulties can affect water quality restoration opportunities. Water is hard to manipulate in a restorative manner, particularly if the restoration effort is directed at improving the quality of water degraded by a toxicant. Degraded aquatic systems generally do not have static, measurable boundaries. This characteristic and the inherent complexities of many aquatic systems impart particular difficulties both in terms of quantifying the extent of degradation and in prescribing remedial or restorative measures. For example, the fate and effects of effluents discharged into estuaries or inlets are influenced by complex water circulation patterns, dilution, geochemical processes and biological interactions. The resultant "impact" will vary as receiving environment conditions change.

Associated with the complexities of aquatic systems is the problem of determining the criteria that should be used in deciding that a given aquatic system should be restored. Some of the available criteria or indicators that can be considered are listed in Table 1. These span the range of lethal and sub-lethal effects on aquatic organisms to the more intangible criteria of aesthetics or expressions of public concern. While there are a number of aquatic quality criteria there are no guidelines that prescribe how such criteria can or should be used in implementing a water quality restoration or pollution control program. While fish mortalities in a specific area might result in steps being taken to quickly resolve a water quality problem, other indicators of water quality degradation do not normally engender a similar response without considerable discussion and debate over the nature of the perceived impact, the significance of the impact, the cost of restorative measures and jurisdictional authority.

Table 1: Water Quality Restoration Indicators

1. Fish mortality
2. Presence/absence indices
3. Biological community characteristics
4. Water/sediment chemistry
5. Tainting
6. Contaminant accumulation
7. Physiological/behavioural changes
8. Pathologies (neoplasms)
9. Aesthetics
10. Public concern

JURISDICTION

In British Columbia, a number of government agencies have some degree of responsibility for water quality issues. Federally, the Department of Fisheries and Oceans, Environment Canada and Agriculture Canada have specific responsibilities related to water quality and the control of toxicant or contaminant use. Within the Province of B.C., the Waste Management Branch, Pesticide Control Branch and Fish and Wildlife Branch are three agencies with significant involvement in water quality matters. Regional and local jurisdictions, such as the Greater Vancouver Regional District, can also be key players in water quality management issues. The presence of these many jurisdictions and associated administrative arrangements between agencies add another level of complexity to water quality restoration programs.

TECHNICAL PROBLEMS

The foregoing legislative, technical and jurisdictional considerations set the stage in B.C. for water quality restoration efforts. A closer examination of water quality issues reveals other possible constraints to active pursuit of water quality restoration programs.

Many water quality problems are the result of ongoing or continuous effluent discharges. Degraded receiving water quality conditions can usually only be restored through upgrading pollution control systems, often at considerable expense. Such discharges are also controlled by conditions specified in permits issued to dischargers under provincial legislation. Proposed changes to such permits thus require considerable federal-provincial consultation, often over protracted periods of time.

Where improvements in effluent quality require major capital investments, particularly during periods of general economic restraint, economic and political factors can significantly affect the successful implementation of restoration programs.

Unlike habitat that has been altered or destroyed by physical activity, problems associated with water quality are not normally highly visible. The contamination of a water body with pesticides or a reduction in lake pH from acid precipitation may not negatively change the visible characteristics of the system. Mine tailings discharged to the bottom of a marine inlet may not be visible in surface waters. Thus other indices of harm must be employed to document impacts and ensure that the assimilative capacity of a water body is not exceeded.

CASE HISTORIES

Iona sewage

The lower Fraser River and its estuary receive a number of industrial, sewage and storm water discharges. At Iona Island on the Fraser estuary, primary treated sewage is discharged into an intertidal area, resulting in extensive water and sediment quality degradation. Problems include organic sludge deposits, sediment metal accumulation and lethal and sub-lethal conditions within the water column near the outfall. Extensive fish and invertebrate kills have been recorded, primarily as a result of severe dissolved oxygen depression within the water column.

Despite the long-standing concern about this discharge and the documented negative impacts on the receiving environment, a final commitment to resolve the problem has still not been realized. A preferred plan has been identified which would incorporate the installation of a deep sea outfall and diffuser to eliminate the intertidal discharge. While this proposal will likely result in the eventual restoration of the degraded intertidal area, other questions have been raised:

- will the deep sea outfall merely transfer the water quality problem from the intertidal zone to a deep water habitat

- is dilution of the sewage through a diffuser system preferable to advanced treatment

- will there be sufficient monitoring to ensure that problems at the deep water site do not occur

- what criteria will be used to determine that a problem does or does not exist at the deep water site

- who will pay for the outfall installation and can administrative and political inertia be overcome in order that the long-standing problem is resolved on an urgent basis?

Marine pulp mills

Many pulp mills in B.C. have been in operation for a number of years. Traditionally, mills discharged their effluents, many of which were highly toxic, into surface waters. As the importance of the near-shore, surface environment for juvenile salmonids and other species became realized, some mills have been required to install submerged diffusers to protect the important surface water environment. Not unlike the Iona situation, the concern has been expressed that this approach may simply result in the transferal of a surface water problem to deep water and a reliance on dilution as opposed to at-source effluent treatment.

Mines

Metal mining and milling results in the production of vast quantities of byproduct material or tailings. In Alice Arm on the north coast of B.C., tailings are discharged into the inlet at depth and are ultimately deposited on the inlet bottom. This form of effluent discharge, while protecting upper water column biological productivity, is difficult to monitor given the depth of discharge and complexities as mentioned earlier, of discharges into complex aquatic environments. It is unlikely that a practicable post-mining restoration program could be implemented given the conditions present in the inlet. Natural biological recovery processes will be necessary to restore, at least partially, the biological productivity of the benthic environment.

Non-point source discharges

Two examples of the difficulties in dealing with non-point discharges are related to sewage discharges from vessels and acid rain.

A growing problem on the B.C. coast is one of shellfish contamination from sewage discharged from pleasure craft and commercial vessels. Shellfish harvesting opportunities in south coastal B.C. have been lost as a result of such contamination. Unfortunately, a resolution of this problem would appear to be complicated by the absence of regulations controlling such discharges and the costs associated with the installation of sewage holding tanks on vessels, onshore pump-out stations and final disposal facilities.

Problems associated with acid rain have been well documented in eastern North America and Europe. Monitoring conducted in B.C. suggests that some salmon streams may be sensitive to pH reductions from acid precipitation events. The control of aerial emissions is, in part, an international one with the attendant problems experienced in eastern Canada. Restoration techniques, such as the liming of lakes to control pH, have been carried out with limited success. Such techniques are costly and are not a substitute for at-source control of aerial emissions.

Summary and future approaches

The preceeding discussion has highlighted some of the challenges associated with water quality restoration. For many effluent discharges that result in degraded water quality, restoration equates with improved effluent quality. This approach will likely continue to be the principal tool in water quality management for continuous effluent discharges. However, a coordinated habitat restoration program should nonetheless encompass water quality restoration opportunities as they are identified. Such efforts could add necessary impetus to other effluent improvement initiatives and is in keeping with the importance of water quality in the maintenance of fish populations and their habitats.

QUESTIONS AND DISCUSSION

(Al Lill, DFO, Vancouver): Are there any opportunities for Fisheries agencies to invest in any kind of improvement works in the lower Fraser? You talk about this $45 million outflow, but is there anything Fisheries agencies can do to help water quality, getting something going?

(Nassichuk): That's part of my job, to deal with the Iona sewage treatment plant and outfall, and in fact, we're doing that. In some quarters, Fisheries people in the water quality field are regarded as radical eco-freak environmentalists. But one of the reasons there is a push in terms of cleaning up Iona, is because of Fisheries involvement, really.

All the work that Ian Birtwell (FRB, West Vancouver) has done in Sturgeon Banks shows that Iona has a dramatic impact. It looks like, with some of his work, we could hypothesize that there are effects on stocks, given the potential mortality that could accrue from the discharge into that specific area.

(James Buell, Consulting Biologist): Under the conceptual plan, is that effluent to be pumped down to the diffusers? What is the density of the effluent relative to seawater, and will seawater tend to push it back up the pipe?

(Nassichuk): Yes, the effluent would be pumped. The oceanographic and engineering work that has been done suggests that won't be a problem.

(Buell): In opening up that little slough (MacDonald) from the north arm across the area of worst impact, is that going to shunt more juvenile fish over that bad area? Will that be a problem, or do you figure that it will flush out pretty rapidly?

(Nassichuk): I think it would probably flush out pretty rapidly. I don't think that would be a problem once that sewage was going out the deepwater pipe, and as long as there wasn't any provision for emergency overflows, or outfalls, in that inter-tidal area, as long as we're sure that it all goes out.

(Buell): And sediments from the north arm will probably cover up whatever doesn't go out?

(Nassichuk): I think that's something we should be looking at.

(John Patterson): You mentioned the $45 million diffuser as a habitat restoration, water quality restoration tool. Once that is in place and you've monitored it, and hopefully there's a noticeable improvement in the water conditions, what other water quality restoration activities might you do in that affected area, relative to the benthic and fish populations that have been disrupted?

(Nassichuk): We would have to look at what would happen with respect to natural solids, or sediment behavior in that area. If there's any kind of natural accretion that will result in covering those areas, it may be best just to let sediment accretion take its course. If not, then in terms of sediment characteristics, there may be opportunities for artificially depositing sediments, removing scouring sediments, looking into a planting experiment, and so on.

(Gordon Hartman, FRB, Nanaimo): You've shown us some maps detailing really extensive distribution of outfalls and sources of pollution. We frequently hear, why worry about these things unless you can demonstrate they're having an impact on stocks, or the number of fish getting into people's nets.

This isn't necessarily my philosophy, but I put it to you, and I put it to anybody else that talks about problems later on, how many times can we show a relation to the actual production of fish from these impacts?

That seems to be one of the things that is a problem within our organization. Certainly, in some circles, if you can't show that it has an effect that's significant in terms of the number of fish getting in somebody's net, then you're just an eco-freak to worry about it.

(Nassichuk): It's really an important question, because this is the kind of thing the department hears all the time. In other words, they're going to say, look, I've been discharging 100 million gallons of effluent per week into this inlet, and look at the stocks, they're healthy. Why the concern for the stocks? Obviously, I'm having no effect.

I agree we need more work to demonstrate more precisely the relationship between a specific discharge and the stock, but that's hellishly complex. First of all, we do run a risk if we basically say, well, if you can't show an effect, don't worry about it. There is the risk of cumulative impacts in many of these areas.

This is why, for example, the Fisheries Act is preventative legislation. We don't have the answers, but there's a tremendous risk of taking a lax attitude towards water quality control.

With respect to the kind of research we need, it would be nice to find an appropriate situation where we've got a small stock. Then we could get into large-scale tagging of juvenile salmon, dosing them with various concentrations say of sewage effluent. Where we had good control over that stock, we could assess returns. It's the kind of work we need to do.

The same question can be applied to what value is a quarter acre of foreshore estuarine marsh in the Fraser. Destroy that, and tell me there isn't going to be an effect on a given stock.

(John Lewis, Fishery Officer, DFO): How far along is the proposal for the diffuser?

(Nassichuk): This week, hopefully, we will be finalizing our position on it. I think basically what we'll be saying is yes, with a number of conditions associated with monitoring and implementation. I fear now that even though this whole proposal has been stimulated by the Greater Vancouver Regional District (GVRD) or the Greater Vancouver Sewerage and Drainage District (GVS & DD), that there may be a certain amount of political inertia associated with this, and it may take some hard work on our part to see this actually implemented.

(Lewis): What has been the anticipated impact on the shrimp trawl fishery off Sturgeon Bank?

(Nassichuk): We're hoping none. With respect to Iona, essentially we're dealing with an effluent that is about 90 - 92 percent domestic sewage. It doesn't have the high contributions of industrial waste that some of the other discharges on the river have.

We're hoping that with that relatively minor contribution, we're not going to have any direct toxic effects, or sub-lethal effects associated with metal contamination, etc.

(Colin Levings): I'll make a final comment on the talk. I think that your plea for water quality work is well taken. I also hope for more interaction between the solid habitat people and the liquid people, because I think that they do tend to break into two camps.

CAMPBELL RIVER ESTUARY RESTORATION AND CREATION

Mike Brownlee
Land Use Unit
Habitat Management Division, DFO

Brownlee, M.J., E.R. Mattice and C.D. Levings. 1984. The Campbell River Estuary: a report on the design, construction and preliminary follow-up study findings of intertidal marsh islands created for purposes of estuarine rehabilitation. Can. MS Rep. Fish. Aquat. Sci. 1789: 54pp.

This report focuses on the cooperative efforts of agency staff, members of industry and the public in developing and constructing a new log-handling facility and rehabilitating an industrialized estuarine area of approximately 32 hectares that had been intensively utilized for log handling activities for over 75 years. Reported are the planning and construction of the new dryland log sorting facility and the rehabilitative measures, the design details and preliminary results of the first year's studies of a longer term program being undertaken to assess the stability and biological implications of the rehabilitative measures, and future studies. Preliminary follow-up study results indicate that the intertidal islands are stable, 93% of the 23,302 marsh cores transplanted are growing, invertebrate colonization is still incomplete, juvenile wild chinook and chum salmon utilize the islands and catches are proportional to the abundance of salmon fry in the estuary. Hatchery reared juvenile salmon do not make extensive use of the islands. Migratory bird use of the islands has been recorded. All studies are continuing.

Key words: Campbell River estuary, estuarine rehabilitation, intertidal islands, march core transplants, benthic invertebrate colonization, juvenile salmonid utilization, migratory bird utilization.

QUESTIONS AND DISCUSSION

(Ron Kistritz, Biological Consultant): You've put a lot of emphasis on stability of these islands. I wonder if you could expand a bit more on whether the geometry of the islands has changed at all, now that you've looked at some elevations and some contours.

(Brownlee): The changes have been almost minimal. We're seeing some sedimentation in a few areas, or we're getting some of the finer material collecting around some of the cores, basically, very minor superficial changes. We left the circular of logs, boom sticks around the outside, and we're getting some wave erosion. Wind and wave action seemed to be more of a problem than river current.

So, I would say that the only changes we are getting are very minor, local in nature, and we're not seeing any difficulties to date because of that.

One of the things we did with B.C. Forest Products was to build in the capability to alter, manipulate, change islands, add and substract, if we thought there were going to be problems. There's a very strong emphasis on evaluation of effort and on follow-up, to examine what is happening, and to be able to modify if difficulties are encountered.

(Kistritz): Has there been a big enough hydrological event to test that?

(Brownlee): We've had 10,000 cfs released (from the John Hart dam on the river). The Campbell's maximum discharge now, according to Hydro, is 19,000 cfs. I'm not saying that there may not be a problem in the future, but given the materials and everything else, I'm somewhat confident that we may not have any real serious problems in terms of erosion.

(Kistritz): What sort of natural recruitment, or colonization of plant species have you noticed, other than the actual species that were planted?

(Brownlee): We're getting a terrestrial species on "Mount Levings" (one of the islands). There's certainly some on "Scrivener's Hump." There are now 23 species that have been noticed in the estuary. Some of those we planted. We had two dominant plant species which we planted in the area, genus Carex and Juncus. These two species were not all that present in the estuary, and we could make a substantial increase to those numbers.

They are found at elevational zones that we think are extremely compatible for fish, in terms of providing nutrition, detritus and food organisms associated with those. It turns out that a lot of what had been identified as Juncus was in fact Eleocharis.

Of the 23,000 cores that we have there, Carex is the dominant, Eleocharis is second, and Onantilla and Juncus are at the third level.

Of the 23 species of separate plants, a significant portion resulted from natural colonization. The half meter centers (transplants) are just about more or less 100 percent now. That's after about two good growing periods. We're coming into the third season now, and the plugs have almost completely grown together after two years, forming a mat. The cores placed one meter apart have not completely coalesced; however the rhizomes are spreading out considerably.

Density of the cores is the same as at Nunns Island, one of our controls. The height of the transplants looks to be about 50 percent of those natural so-called undisturbed control areas.

(Colin Levings): I'm going to be speaking on some of the follow-up studies that were done on the Campbell River estuary. I want to acknowledge the cooperation of B.C. Forest Products, who helped with some of the benthic studies that I'll be describing.

FISH AND INVERTEBRATE UTILIZATION OF CAMPBELL RIVER ESTUARY ISLANDS

Colin Levings
Fisheries Research Branch
West Vancouver Laboratory, DFO

The Campbell River estuary is located in the northern part of the Strait of Georgia. The station locations in the outside part of the estuary and the marine zone consist of stations that are spread from Campbell River to Deepwater Bay; a distance of 10 or 12 kilometres.

Inside the estuary, the fish and benthic sampling stations were aligned with the man-made islands and the habitats existing before the islands were made. Behind Tyee Spit was designated estuary habitat. The transition zone included stations in the brackish area where salinities are reduced somewhat. It was felt that fish could move in and out of this transition zone, depending on the tidal cycle.

Sites within the estuary are near the mouth of North Baikies Slough (Station 7); the transition zone habitat and eelgrass bed in a low-tide refuge in Painter's Channel (Station 34). Typical marine habitats in Discovery Passage include rocky beaches, sand beaches and in some instances, kelp beds.

Juvenile chinook catches peak first in estuary habitat followed by transition and marine. The latter are lower because the fish are moving offshore and not all are available to our beach seines.

We think that the time difference between the peak catches are evidence of residence time. Coho move through the estuary quite rapidly. A large number of coho came through the estuary in 1982 from hatchery releases. There are not too many data on wild stock coho in the area. We think the estuary peak for chum is the local Campbell stock fry, showing some evidence of residency.

The rather diffuse peak of chum fry observed later on are thought to be migrating stocks of chum, possibly from the Fraser River.

Pinks showed somewhat the same situation as chums with the local and migrating stocks. As shown in other estuaries, there is not much evidence of residency for pink in the estuary.

In 1982, there was not a significant difference between the islands and reference habitats. Abundance definitely varies from year to year and utilization seemed to be a reflection of overall abundance of wild chinook stock in the estuary. Use by hatchery fish was significantly lower.

In 1983, use of the islands by the wild fish was decreased, with CPUE (catch per unit of effort) 1.6 compared to 32.6 in reference sites. The hatchery fish once again showed little use of the islands. The ratio of wild to hatchery fish in the two habitats was about the same.

The important factor of island configuration, at least in 1982, seemed to be the proximity to the river channels. The west channels are the ones closest to the river on Island Number Three, which is the one with the many channels; some were built facing upstream, some facing downstream. For chinook especially, the ones in the west had a much higher catch per unit of effort than the ones on the east which was the non-river side of the channel. The upstream and downstream orientation, at least for chinook was not that important. We did some further studies this year with an intensive bit of sampling in May 1983 where a different sampling strategy was used.

Results showed that chinook fry were scattered throughout the islands. There were a couple of spots that seemed to show relatively higher catches than others. Once again, these sites were on the river side of the estuary.

Some work has been done on the feeding of the chinook and chum in the island habitats. We've only got the data worked up for 1982 and the sampling at that time was not as complete as desired, so we had to combine the data from sampling periods in early, mid-spring and late-spring.

There was certainly evidence that wild chinook were feeding in Island Number Three, but there are many more detailed analyses to do.

Invertebrate studies were funded by B.C. Forest Products in 1982 which involved quadrat sampling in the vegetated and non-vegetated habitat. Abundance of some of the more common invertebrates within the estuary were tested with an analysis of variance to see whether there was any statistical difference between the four islands and the reference island, Nunns Island. Corophium, a common amphipod, was more abundant on Island Number Three than at Nunns. Another kind of amphipod, Eogammarus, was more abundant at Nunns than it was at the other islands. For insect larvae, there was no statistical difference between the reference island and the other ones. When the total macrofauna community was examined for 1982, there was a statistical difference between Nunns and the other four islands. In the first year, there was no evidence of massive recolonization, except for selected species. In summary, the community had not converged in the first year.

If we compare the abundance within the four islands themselves (excluding Nunns Island data), once again, with respect to insect larvae abundance, there was no statistical difference between the four islands. For Corophium and Eogammarus, Island Number Three seemed to be one of the islands where colonization happened fastest.

For some islands, it seemed to matter little if there was any vegetation there or not. The dependence of the species on vegetation is tied into the life history of the organism. For example, Corophium does not really require vegetation, as it builds a tube in mud, whereas insects are strongly tied to vegetation.

The data are not completely analysed yet for 1983, but a cluster analysis showed that the natural and island communities in 1983 were not converged as of that time. I think it will be a few years, probably three or four years at least, before we see a total convergence. However, I should point out that this work is not measuring productivity, only standing crop of benthos.

With respect to evaluation, I would like to comment on the types of fish which are using the islands. The importance of hatchery releases to the estuary has been increasing, that is more and more chinook are being put through the estuary. Of the fish that are spawning naturally, there is a pattern of decreasing escapements in the Campbell and increasing escapements in the Quinsam. The wild fish that we are catching are, in fact, using the islands and are probably a mixture of fry derived from the Campbell and Quinsam Rivers.

In terms of fish production, it appears that, at least for within-estuary use, we are benefiting the wild fish, although I wouldn't want to exclude the importance of producing food for hatchery fish which do feed in the estuary.

Our conclusions are that the fish use of these islands is related to the overall abundance of wild stock in the estuary. Comparing 1982 to 1983 and 1984, there were many fewer wild fry in the estuary and there is the impression that when there are more fish, there will be heavier use of the islands. The wild fish appear to use it more than hatchery smolts, but this may depend on smolt abundance. For the chinook, at least, the proximity to the river is highly relevant, perhaps more than channel orientation. The invertebrate communities are not yet convergent with the reference sites but colonization of some species did occur rapidly and the animals appear to be used by the fish in the islands.

QUESTIONS AND DISCUSSION

(James Buell): I noticed from your last slide that there was an apparent pattern of use in the transition zone that appears to reflect the pattern of use in the artificial islands, but does not tend to reflect the pattern of use in the natural habitat. Is there anything to be concluded from that?

(Levings): There are data there. It's just that that particular slide was a summary slide, which included both hatchery and marked fish. So there were some details that were lost.

(Carey McAllister, FRB, Nanaimo): One difficulty in fishing the artifical islands, is that we're very heavily dependent on tide, so our data for the artificial islands are not as comprehensive as they are for the transition zone, or other parts of the estuary. So, I'd be very cautious about reading anything into those differences.

(Buell): There's a new area where they're now sorting logs. It's an aquatic area, and early on, as I recall, there was some talk of opening that, or putting either a culvert or breaching that causeway to get some flushing through there. Did that ever happen, or will it?

(Mike Brownlee): One of the design details was the placement of a causeway from the river channel underneath the dryland sort into that impoundment. The depth of the water inside the impoundment was approximately three meters.

We've done some rather detailed water quality efforts at the insistence of the Habitat Management Group, and it would appear that with the culvert closed we were getting some dissolved oxygen (DO) depressions. We've done some experiments now of closing the culvert, and assessing the lower waters in that impoundment. We found DO depressions, but the lowest that we've got so far, if I remember correctly, is about 35 to 40 percent saturation.

We're looking at 60 to 70 percent saturation compared to control areas, so they were consistent with control areas with the culvert open, but we want to look at that a little bit more.

(Don McQuarrie, DFO, Vancouver): Who paid for the development of the Campbell River estuary, and how much did it cost?

(Brownlee): B.C. Forest Products, mainly. We put up some monies towards vegetative transplant.

Their cost of the actual construction of the dryland sort is four and a half million dollars, the cost of the island work they estimated at $250,000. I think there's been some juggling of numbers on their part, because we used 30,000 cubic meters of material to build those islets. That material had to be moved anyway, but I think that they viewed it as an expense of this project.

We made use of a program that was complementary to their dredging. It's a bit of a site-specific determination, but their estimate was $250,000 for the cost of the islands.

We haven't sat down and looked at DFO's costs of evaluating this project. They're miniscule, really. We're looking at a minimum of at least a five, six year study to determine how effective we've been with this project.

When it's all done, it will probably add up.

In addition, there has been a very detailed fish transplant study at Quinsam hatchery; 35,000 fish have been put in four different locations. All 140,000 fish are nose-tagged so their return as adults, and contribution to fisheries, can be determined. Those fish have been released in riverine areas, estuarine, and the transition and marine zones.

With follow-throughs, and all the rest of it, the total costs of this project will be rather substantial.

(Jim Morrison, DFO, Nanaimo): You presented data on fish use of the natural estuarine areas versus the islets. Did you collect any data on fish use of the log boom areas prior to them being moved out and the islets being created?

(Levings): Yes, there was actually a fairly detailed study done in 1980 by Raymond et al. We have the information on invertebrate use from 1980 as well. In fact, there have been several studies over the years, but Raymond et al in 1980 was perhaps the most comprehensive, as well as Goodman and Vroom (1974). We haven't compared those data yet, but we will eventually.

SMALL ESTUARINE DEVELOPMENT AND RESTRUCTURING

Gordon Ennis
Water Use Unit
Habitat Management Division, DFO

I'll be talking about two projects that have been carried out in the last year. One is at the Pacific Coast Terminals' site in Port Moody and the other is in Gundersen Slough on the lower Fraser River, B.C.

The Pacific Coast Terminals' project combined habitat improvement with a proposal that called for filling a saltwater marsh and mudflat. The people involved, besides myself, include Mike Flynn, Rob Elvidge, Kevin Conlin and Bob MacIndoe. In addition, consultants to Pacific Coast Terminals, John Jordan and Christine Binder, have been quite involved.

The type of habitat that the company proposed filling is saltmarsh. The primary species are Carex lyngbyei, Glaux maritimus, and Juncus effusus. In total, they proposed to fill about 1,500 square metres of saltmarsh and about 500 square metres of mudflat in the Port Moody area.

The saltmarsh is now great habitat for ethelyne glycol tanks and styrene monomere tanks; no longer very suitable habitat for fish.

In trying to resolve this and in recognition of the productivity of the area, we set a goal of creating two units of habitat for one lost. This was partly in recognition of the risks involved in creating new habitat compared to the known existing productivity and owing to the time it takes for new marshes to be fully productive. The approach that we used was to survey the existing vegetation that was to be filled and to divide the work into two phases, mainly because of logistics. During the first phase, prior to filling, we removed an area of an upland habitat, trucked it away, thereby creating new aquatic habitat (called site "A"), then transplanted marsh plants into the site and carried out an assessment. The second phase of the work will also involve removing a nearby upland area (called site "B"), and that hasn't yet started. The second phase could not be started immediately as the site was used as a marshalling area for the company to store their materials while they were building the facility.

Work started in July 1983 with removal of upland materials. The existing marsh was removed with a Hitachi excavator using a 72-inch bucket. It takes blocks of marsh that are 6 x 4 feet in measurement and it takes 40 centimetre depth of sod. When we made the new habitat, we scooped it down 40 centimetres lower than the elevation at which the marsh plants were growing, so that on balance they would be at the same elevation. The marsh plants, taken out of the site to be filled, were placed on metal three-sided pallets having one edge without a raised side. The pallets were put on a truck and immediately moved to the area to be transplanted.

The marsh materials were initially placed into the new area by a method using slings that were attached to the bucket of the excavator. Eventually, we had to go to a crane to sling them down.

When the sods were put in place, we did a post-assessment about a month later and we found that 20 percent of the marsh plants had disappeared by a combination of removing them, trucking them and putting them down. Fill was used to bring the material between sods up to level. However, upon examination, about eight months later, it was observed that the surface was not flat as expected and standing water was observed within the new marsh. One other problem that developed was some erosion from the uplands slope. Suspecting this might occur during construction, we constructed a gulley between the artificial marsh and the upland area so that any sluffing would not cover the marsh plants. We also created six tidal channels to flush the area. It would begin to wet at about an 8-foot tide.

Erosion occurred between the natural untouched bank and the new bank. When we did a preliminary evaluation in April, we found quite a bit of concrete dumped over the side. At first, we thought it was just operators dumping excess load, now we understand it may have been deliberately put in the gulley to stop erosion. The concrete has sluffed right into the marsh itself and covered some of the marsh plants. This was done without consultation with DFO.

Some grass has started to form above the high-water mark. This was hydroseeded in August 1983. We had looked at getting it sodded and it cost 10 times as much as hydro seeding, so the company chose that route. They were also requested to put trees along the slope although that hasn't occurred yet. There is more work planned for later this summer and fall.

The materials in the scooped-out area were really quite messy; it was old fill, probably put in around the turn of the century and there was a lot of iron in the material. Oxidation of that iron was visible. In fact, in the existing marsh we were not always able to take away a 40-centimetre piece of sod because of wood chips underneath.

Project monitoring was required in order to evaluate the effectiveness of the work. In July, after we did the transplanting, we had the new area mapped in order to obtain an initial record of the vegetation distribution. Site visits were conducted in July, August, September; photographic records were the extent of the evaluation. In fall '84, there's going to be one more evaluation on the success of that transplant.

There has been new growth observed this spring, and the consultants feel that the 20 percent loss that had occurred in moving these 4 x 6 blocks will probably grow back quite quickly by new growth of rhizomes in between the pieces of sod. Most of that 20 percent loss was for the tall plants, like Carex, rather than for the smaller plants.

It cost about $5,000 to do the monitoring prior to any work. The machinery costs were $80,000 and the survey monitoring mapping costs were estimated to be $10,000. The total cost was therefore about $95,000 for this first phase.

The work on the second phase has yet to be done. We're beginning to look at plans for that now.

Gundersen Slough on the Fraser River, near New Westminster, represents a different type of estuarine restructuring. It is a project begun by core habitat staff and taken over by the New Westminster office once staff relocation took place.

Along the north edge of Gundersen Slough, there were unstable banks that were falling into the water. It was a ubiquitous rather than a localized problem. These sluffing banks were destroying what little marsh habitat did exist along the north bank of the slope. It's hard to pinpoint why this occurred. It's our view in Fisheries that it's probably dredging-related. Gundersen Slough is a harbour for fish boats and Public Works of Canada recently dredged that slough. The dredging guidelines in place, should have prevented any problem. But, what we suspect happened is that during dredging the fish boats, moored at the shore, turned on their props and the prop wash subsequently washed materials into the dredge site. That may have been the cause of the problem; the fishermen and Public Works deny it.

Illegal filling also took place. The fishery officers, in some of their habitat surveillance work, noticed piles of fill, ready to be pushed into the water to try to stabilize these banks. They were eroding to such an extent that fences were starting to fall into the slough. One leaseholder was worried about buildings on the uplands.

It was a hard problem to deal with on a leaseholder by leaseholder basis. We wanted to take this slough and deal with it as a whole, rather than on an individual leaseholder basis.

We did some biological sampling in the area to determine habitat values. Invertebrate numbers were low, around 4,000 per square metre, and those were mainly nematodes and some tardigrades. We did find some sculpins; but juvenile salmon were not observed in the area where this was occurring. So, habitat values were much lower than at the previously discussed Pacific Coast Terminals site in Port Moody.

We were able to deal with Gundersen as a whole, instead of trying to solve all these little fills in a helter-skelter fashion owing to the cooperation of the Fraser Port Corporation.

We had several meetings with Fraser Port, who manage that land, and Public Works to try to get agreement on how to proceed. Eventually, we got agreement to try and restabilize that bank. We carried out biological/engineering surveys; for instance, we took a lot of heights of where plants were growing in adjacent marsh. (Juncus and Carex were the common marsh plants on the south side of the slough where marsh is extensive.)

We designed a plan for a new slope to reflect the data we collected. Our plan called for using riprap from the top to the bottom of the bank, to stabilize it. We also created a pocket at the correct depth in which dredged material was to be placed so that marsh plants would grow.

The dredged material placed in the dredged pocket consisted of subgrade fine silts. At higher elevations the bank was stabilized with dirt that had sods in it, and grass seed.

The work has just started this year, and there has been no evaluation.

Equipment costs were $65,000 and labour cost about $5,000. The total cost was about $145,000.

(Editor's note: The author supplied the following update for publication in the proceedings.)

1985 EVALUATION UPDATE

Pacific Coast Terminals habitat creation was done in two phases. The first phase at site "A" (described above) involved transplants of Carex, Juncus and Glaux. The Glaux has succeeded at site "A" but the other species have failed. These results are speculatively attributed to dry 1984 and 1985 summers and to cropping by Canada geese.

The second phase of work was performed at nearby site "B" and involved standard core methodology transplants of Carex. This site also failed probably owing to the same factors as at site "A". Remedial works of a physical nature are planned for site "B" to be followed by further transplanting in the fall of 1986.

QUESTIONS AND DISCUSSION

(Al Lill, DFO, Vancouver): Who paid for the work?

(Ennis): Harbour Commission paid for the Gundersen Slough work, and their proponent paid for Pacific Coast Terminals' work. DFO gave staff time.

(Mike Brownlee): You mentioned 95,000 for the first one, and a hundred and something for the second. What were the two areas in terms of extent, two acres, one acre, half an acre?

(Ennis): For Pacific Coast Terminals, I guess the fill would total about half an acre, and about an acre of compensation.

(Brownlee): So, an acre of marsh for 95,000 on the first one, the second one, 145; what was the extent of that area?

(Ennis): I don't have those figures at hand for Gundersen Slough. I would say that the unstable bank is about a mile in length.

(Colin Levings): So, a mile by a couple of meters wide?

(Ennis): Yes.

(Levings): What's the commitment from the proponents to monitor these projects?

(Ennis): There is a commitment from Pacific Coast Terminals to monitor, with a monitoring plan acceptable to us. For the first phase, I think the monitoring will end in fall '84. We haven't even discussed the evaluation of the new phase which has only considered vegetation, not fish.

For Gundersen Slough there's been no demands put on the proponent to do any monitoring. We were happy to find some resolution to the problem, frankly.

(Brian Tutty, DFO, Nanaimo): Mike Brownlee mentioned there was an element of coercion in the Campbell River because it was a high profile habitat, and it was particularly productive.

In Gundersen in particular, what was the element of DFO involvement that identified this as an opportunity? From what I understand, it was a particularly poor opportunity to have that kind of investment.

(Ennis): I would say so, I guess. If we were using DFO funds, and if I was sitting on some board evaluating projects, I wouldn't have picked Gundersen.

Nevertheless, there was some habitat there. There was, I suppose, an element of coercion in the fact that the leaseholders, that Fraser Port leased the land to, were beginning to suffer property damage, and they had to resolve it somehow. There wasn't much coercion used, though. It was in this case, almost an evolution of dealing with the Harbour Commission. We've had many dealings with them in the past. Certainly, since I came on staff, there's been numerous correspondence between DFO and the Commission related to the importance of riverine marshes to fish. We would respond to those, and we would show data such as Westwater was collecting, and try to indicate the importance of these areas to them. I think in part they were beginning to accept that these marshes are valuable fish habitat.

And so, they seemed very willing, really, to build these extra costs into their plans.

I mentioned the cost of the rock, but they probably would have had to do something anyway to protect that property, and they did go a little further to give us some benefits.

(Tutty): Let me maybe goad you a bit more. If the landlord, in this case using his funds, was willing to go to this extent to cooperate with us in very marginal habitat, perhaps it would have been better to use those resources in a particular advantageous area where you could have done some real habitat improvement work within the same area that the landlord owns, the lower Fraser.

(Ennis): I'll take that as a philosophical comment.

(Tutty): I'm thinking of no net loss of fish habitat.

(Ennis): I would be inclined, with no net loss, to try to keep it as site-specific as possible. If there's work to be done in other areas, come up with those funds from the people involved, or else ourselves, if it's not man-related.

(Duncan Hay, Consulting Engineer): I would just like to make a comment on that last bit of goading there. The cost of enhancement in engineering projects is often not very much. In this case, the problem was to protect the bank, and what you did with the step profile was to actually involve a little enhancement. The money would be spent to protect the bank anyway. I think that was your point.

(Ennis): Yes.

(Hay): And the point I want to make is, usually in an engineering project, you identify what you can do to enhance it, and be proactive in the development. The cost of that is usually a pretty small portion of the total engineering solution.

(Ennis): Good point.

NANAIMO ESTUARY LOG STORAGE AREA—ESTUARINE RESTORATION

Carey McAllister, Head
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[Transcripts of this presentation were not available for publication.]

QUESTIONS AND DISCUSSION

(Eric McGreer, Biological Consultant): I think I can perhaps touch on a few points that Carey made. I feel that it relates both to the way biologists have approached studies on the coast in the last number of years, and perhaps to the contracting-out process as well.

At the start of this study, it did come out as a request for proposal, and as the consultant involved, we didn't know where the background to that came from.

Carey mentioned this morning that it was sort of hastily prepared. I think that probably relates to asking the right questions. Since completing this study, or as I've talked to various people within the Department, and others, the initial question everybody has, is how does it relate to fish? The study, unfortunately, was never set up to look at fish, it was set up to look at benthos.

If that was the objective, that's fine, and if it wasn't, then that's an area where some communication didn't occur. Transferring the results directly to the fish populations would have necessitated a different study design and different measuring techniques.

Another difficulty we've had, and I've had it happen in a lot of studies, is when we went to select the sites to study there's always a problem in estuaries of looking at what's the appropriate reference station. There were a number of reasons we chose the sites that we did, based on either previous knowledge in the estuary, or lack of knowledge. But one thing the study didn't involve, in terms of the recovery aspect, was a feasibility study. Having worked with a number of engineers in the last couple of years, I see that the engineers, more so than the biologists, tend to do an initial feasibility study. They look at a number of sites, see which might be appropriate, look at various parameters for the major study of what you're looking at, whether that be recovery or rehabilitation.

There's a real need on the part of biologists and fisheries managers to do that feasibility study first, to gather some initial information, where it doesn't occur, before making a real choice of the actual sites which should be the focus of a larger study.

In the past, there's tended to be a one to one relationship between a consultant and the principal scientist, and the scientific authority on the part of the government service. I think it worked very well during the '70s when the questions we were asking were relatively straight-forward, like the effects on A and B, or a short-term study.

The kinds of questions we're asking now in terms of biology are so multidisciplinary and so widespread that there needs to be more communication in terms of the actual ongoing study; with a larger group, whether it be a task force, or funding agency, or whatever. I've had the experience in other areas where people funding a study wanted certain specific pieces of information out of it, or specific questions answered. They hadn't followed the study far enough along. At the end, when they got sort of a draft report, after a year-and-a-half or two, they found they weren't getting information they required.

So, I think that kind of extra communication is very important.

(McAllister): There are some major differences between the Campbell reclamation and the Nanaimo reclamation. The Campbell reclamation took place without the benefit of a highly bureaucratic task force, or task forces. Decisions were made very quickly. It was implemented fast, and there was a very intensive follow-up which will continue. This is definitely not the case in Nanaimo.

One thing they do have in common, though, is that both reclamations were prompted by a site-specific proposal. Another thing they have in common is that once the site-specifc matter was dealt with, we all went back to our tents. In the case of Nanaimo, we still have dikes, we still have major areas of log booms, we still have the effects of any kind of environmental activity going on around the Nanaimo estuary, which we're not really addressing.

There was no real area plan for the Nanaimo estuary, or even the watershed. This is true for the Campbell, too. Having reclaimed the estuary, or part of the estuary, other parts of the watershed are going to hell in a wheelbarrow. We're not really addressing that.

It would be nice if these reclamation projects could be put into a larger area, or district planning context.

(Higgins): Was this put in as part of your biological program review for this year, the continuation study?

(McAllister): No, not for this year, because as of 1982, Colin Levings and his people were committed to the Campbell estuary.

(Higgins): Do you see the formation of the Area Planning Committee having any bearing on this. Already, we've had two meetings and we've had two different actors attending from the Research Group at those meetings. The last one who was there, I was very concerned about his role; whether he's a puppet or not, or whether he has any actual meaning there.

(McAllister): I don't think he's a puppet any more than you are, Rick Higgins.

With respect to the issue, the Area Planning Committee could certainly be used as a forum for identifying the need for more follow-up on the Nanaimo estuary, or any other estuary. It would be a proper place to identify the need if it is perceived to be a priority need.

(Buell): You probably shouldn't take much solace, but we have the same kind of bureaucratic problems in the lower 48. Every time we have a big task force, less and less gets done, slower and slower.

Getting back to the science of this, in some conversations with Eric on the telephone, he suggested that it was his suspicion the lack, the slow rate of convergence, if there was any, between the two benthic communities--inside versus outside the booming area--was perhaps due, at least in part, to a very low percolation rate of water into the benthic substratum. This produced anaerobic sediments very close to the substrate surface. It seemed that a possible mitigation or rehabilitation technique would be somehow to turn over the sediments artificially, perhaps by borrowing a large disc from a local farmer.

I'd like your reaction to either the hypothesis that the percolation rate has something to do with the very low rate of convergence of the community, and second of all, the notion of trying to reaerate or fluff up the benthos after log booming is removed from a flat.

(McAllister): The idea of breaking up the compacted sediments sounds useful to me, at least as a pilot project. I'm certain that the compaction and the anaerobia close to the surface was a factor in the biology of the area from which the booms were removed.

As to convergence and recovery, Eric observed as a result of the study that the control area was probably also highly disturbed due to a new river channel being formed, and a lot of sand being piled over that, and over the other areas. So it's quite complex.

(Tutty): With regards to the continuation of the program which died, would you care to let us know where the program died? Was it, in fact, submitted as a program to DFO, and where did it die?

(McAllister): I was away at the time, and I don't have the details. I have been told that people at the Biological Station did submit proposals for additional investigations on the Nanaimo River estuary. If it died, it would have died within the Fisheries Research Branch.

(Lill): There was one topic that was not discussed today at all to my satisfaction. We didn't talk about the Squamish estuary, or about river training structures, like we find on the Squamish estuary. I noticed a lot of studies were done of the effects of this training, and on whether fish coming out this way, come back and colonize and use these areas.

We did put a little port in this structure at one time, I don't know whether or not it had any effect.

I would like to have someone comment on the disadvantages or advantages of porting some of these kinds of training structures. Is there any thought about where training structures actually might be beneficial in making an estuary more productive?

(Buell): There was a similar deal that was done near LaConner in Washington, at the northern end of Puget Sound. There was a training jetty at Swinomish Channel. The tide rips through the Swinomish Channel pretty wild. A lot of juvenile fish used to go up the Swinomish Channel and migrate north. When the training jetty was put in to prevent silting in the channel, which is also used by both commercial and pleasure boats to a great extent, they got very little juvenile out-migration through the channel. They all went around.

The corps came back and put some fish gaps in there so that the fish could go through, but most of the silt wouldn't. Some fish went through. It alleviated the problem somewhat. The Swinomish Indians used to be able to really harvest those fish as they came back through the channels, especially at low tide, when they were virtually trapped in there.

The runs haven't depleted so much, but the migration routes have. There was some concern that the rearing area is of slightly lesser quality in the present out-migration route, but there are no firm data that suggest that the runs have declined.

The fish gaps have worked somewhat; people have monitored fish passage back and forth. Maintenance hasn't been what it should be, and the passages are starting to fill in.

If you do something similar; make sure you have a maintenance contract to keep them clear of sediment. You might talk to the Washington Department of Fisheries about that. They have been monitoring that to some extent, and there are data available.

(Levings): Rick Higgins was involved in a similar project on the Steveston north jetty a number of years ago.

(Higgins): About 900 meters or more of the jetty were broken down. We studied over a two-summer season some of the areas that had crumbled down. We put nets in to try to determine whether it was going to allow fry easier access from the Fraser River onto Roberts Bank. We felt there wasn't much utilization by those areas, because there's the shear along the Steveston jetty that naturally would deflect the fish away. Where the area on Roberts Bank goes adjacent to the ports in the jetty, or the break in the jetty, there's actually a degrading of habitat there.

If you're looking for creating something, you're not going to create habitat there, you're actually going to degrade it and erode it away.

(Lill): By putting the ports through there?

(Higgins): By putting the ports through the jetty.

(Buell): From the velocity?

(Higgins): Yes.

(Levings): I think the Squamish situation would be a bit different, because there is sort of a buffer of riparian vegetation between the main river and the jetty. But, there certainly were a lot of fish using the ports, on the Fraser, weren't there?

(Higgins): Not as many as to be expected. They did a study on the other side, on the main current, to see what was passing, versus what went through, and a very small percentage actually went through. Most of it deflected from the current.

(McAllister): Would that apply to sediments as well as the fry?

(Higgins): We didn't study the sediments.

(McAllister): There was some interest in ports as gates for sediment to get through, through onto the bank as well, was there not?

(Higgins): Yes, we were working with Al Tambury. He was supposedly going to give us a reading on whether it was actually going to accrete, but it wasn't accreting there at all.

There's an actual scour hole formed on the other side, and they're thinking of trying to revegetate that area, because it's fairly stable.

(Lill): What kind of habitat can you improve by putting in training structures directly? Is there anybody who would like to comment on that?

(Levings): As you probably know from the work we did on the Squamish in the early '70s, there was some evidence of improved primary, and possibly, secondary productivity behind the jetty. But like many of these types of projects, the control or the reference for the project was not that good, in my opinion. There should be further work on a small estuary and pilot study to look at that specific problem.

The velocities behind the jetty were reduced so that sedimentation on top of the marsh and algal communities was reduced. There was some evidence from studies of primary production, that levels were higher there. Whether this was translated into fish production, of course, is the major question that we're all groping for. There's certainly no evidence that there were fewer fish behind the causeway compared to on the riverside of the causeway.

On the other hand, there may have been fry jetted out into Howe Sound and excluded from the estuary by virtue of the causeway being there. That was not looked into.

(Ennis): When we're talking about jetties and causeways, it may be worthwhile to mention Roberts Bank, as much as I dread it. When the Roberts Bank coal terminal was put in, there was about a five kilometer long solid fill causeway put in. The eelgrass behind that causeway has increased by about 170 hectares. It's an incredible increase. On the river side of the causeway, there's been no increase.

So, there's been an increase in the amount of good habitat. It's hard to say how that translates into fish, because there's not been any real prior assessment, and we don't know whether the causeway has affected the ability of fish to utilize that habitat.

(Levings): Some of that expansion was due to an annual eelgrass compared to a perennial eelgrass. So, the net production may not be relative to the net area.

(Harder): I've been working on the Annacis Island project, and there're two causeways that we've been looking at; one at the Pambina Swing-Span Bridge structure, and Rabbit Island, down by the Dow Chemicals site. There's no preconstruction monitoring data there. These two causeways were put in in the '60s and late '50s, but the vegetation that's developed there, and the fish abundances that we've found were, on a relative scale for that section of the river, very productive.

We found our highest fish densities in both those sites, and we were doing sampling from New Westminster down to just above Steveston Island.

(Buell): At the north end of Swinomish Channel, there's another small lagoon that was formed when a piece of intertidal area was cut off from most of the tidal flats by a railroad causeway. They left a bridge there for the tide to run in and out, and when the tide did that, it made a scour hole underneath the bridge. It's quite deep and changed the deposition patterns in what had been a mud flat. It increased the number of distributaries, and so forth, and also increased the amount of marine plant life, not so much eelgrass, except in the distributaries themselves. I bring this up because when we sampled up there we had by far and away our highest densities of both chinook and pink fry in that area. We also had high densities on the channel side, where the causeway had changed the tidal flux patterns, and had caused more distributaries to form.

It was an increased network for channels. At high tide, it seemed like the fish were concentrated in the areas which had the distributaries, even though the water column extended over the entire flat.

We could see them very actively feeding, as the tide went out. Where all the distributaries came together, they would just school up and peck away at whatever was floating down the tidal currents that were coming out of the little channels.

With respect to Roberts Bank, it occurs to me that a similar eelgrass community established itself on the south side of the ferry terminal there. That eelgrass community wasn't there until the ferry terminal causeway was built, and then it established itself, as I recall.

The other side of the issue, though, is that juveniles migrating down across the flat area have to run the gauntlet, as it were, around the end of the causeways. I don't know whether anybody substantiated this, but it was felt there would be a rather substantial exposure to predators in the deep water areas.

They wouldn't have the shallow refuge, they wouldn't be able to just stick to the very shallow areas, and would be running the gauntlet at the end of the causeways. I don't know if anybody's ever studied that, but there was certainly a lot of discussion.

(Levings): I think that many of the points I'm going to make are appropriate for the other types of habitats, be they rivers, or creeks, or streams, or whatever, because they're more general issues.

We've touched on how to evaluate improvement, especially in estuaries. We've discussed both the philosophical and the scientific part of it. How do we recommend or suggest that some improvement should indeed take place in an estuary? Water quality criteria exist, but habitat quality criteria are much more difficult to defend, at least from my experience.

We've talked about the research on consequences for populations versus ecosystems. This is the one that I think Gordon Hartman picked up on this morning, and it is an issue that certainly merits study.

I think that we have a group of people, a committee in the region, which is interested in a coastwide approach, or at least in trying to collect information on what we should be doing in what areas.

I think that somewhere along the line we're going to have to decide on some pilot studies, intensive pilot studies. Are we going to do projects over the whole coast, or are we going to do it within a certain subdistrict within an estuary?

I think that we're going to have to decide how to catalogue these opportunities that we have. It seems to be a difficult thing to do, even in a relatively intensive and well-described area, such as the lower Fraser River.

We've had talks about clearing houses, over the years, but nobody's ever really grabbed the thing by the tail and tried to get it together. How do we keep studies underway long enough to document effects? I think that other projects, such as Carnation Creek, have documented long-term cycles in effects. How do we cope with things like long-term climatic changes when we're measuring effects?

Finally, one of the major developments on the coast is mariculture.

How can we, working in estuaries and coastal environments, contribute to this; through impoundments, through release of so-called nomad coho fry? Will they rear in estuaries, can we yet optimize the use of some of our coastal environments?

(Patterson): Certainly, the need exists to develop a system to identify the opportunities, and to follow up and evaluate the effectiveness of the prescriptions we're identifying in a regional sense. Hopefully, through the integration with our stock management, salmonid enhancement, habitat management and research programs, we will be able to achieve this integration.

SESSION II—LAKE HABITAT IMPROVEMENTS

Introduction by:
Art Tautz, Director
Fisheries Research Section
Fisheries Branch
Ministry of Environment

The Fisheries Research Section is constantly working in a number of areas dealing with lakes and lake habitat improvement, as well as lake management.

I would like to make a few introductory remarks about lakes in general, and particularly, in relation to the status of improvements in estuaries. Lake limnology has been going on for quite some time, relative to the estuary work, and it's a much easier place to do research. We have a self-contained system. The fish don't seem to migrate too far away.

I am the provincial representative for the Salmonid Enhancement Program (SEP). I have been active in the SEP Opportunities Committee. We have tried to look at lakes, in particular, as enhancement opportunities for salmon, or at least we have discussed that as one of the possible enhancement techniques for SEP Phase II.

We can tinker around with lakes to a fairly significant degree, and we can have a fair degree of comfort in the results that we're going to produce. We can aerate lakes; we can super cool lakes to the point where a fisherman dropping a lure in can turn the thing into an ice cube, which isn't necessarily a desirable thing. We can pretty much control the types of algae that are in some of the lake systems, with the appropriate mixes of nitrogen and phosphorus.

Micro-nutrients have been identified as limiting factors in a number of areas. Their addition can enhance lake productivity. In addition, lake storage has been an area of improvement. We have the opportunity for creating lakes. All in all, I suppose the technology for tinkering with these lake systems is fairly well advanced.

Before we get too enthusiastic about the opportunities, though, the management practices that go along with the improvement techniques have to work. We don't really want an improved lake where we don't have an appropriate and well-planned management strategy to complement it.

SOME OPTIONS FOR HABITAT MANIPULATION IN B.C. COASTAL LAKES TO ENHANCE SALMONID PRODUCTION

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ABSTRACT

The Fish Ecology Unit of the Lake Enrichment Program has conducted research on factors controlling production of sockeye salmon in lakes of the outer B.C. coast since 1977. Experience of this group and others indicates that optimization of sockeye (Oncorhynchus nerka) smolt production in lakes lies in the manipulation and control of habitat components that influence food production, fry recruitment, abundance of competitors and possibly predators. Controlled additions of inorganic nutrients to coastal lakes have been used to increase production at primary and secondary trophic levels to increase in-lake growth (Hyatt and Stockner, 1985) and survival of target species such as juvenile sockeye salmon (Le Brasseur et al, 1978; Hyatt et al, unpublished data). Numerical responses by non-target species (largae diatoms, blue-green algae; low value zooplankters; threespine sticklebacks, Gasterosteus aculeatus) have significantly reduced benefits of nutrient additions for sockeye in a number of years and lakes and indicate that other methods of habitat manipulation may have to be developed for use in tandem with lake fertilization to consistently achieve maximum production of sockeye (Stockner and Hyatt, 1984) Control of the amplitude and frequency of seasonal variations in lake-level is identified as a habitat manipulation option with considerable potential to influence recruitment, growth and survival of salmonids, their competitors and predators. Other options for lacustrine habitat manipulations are discussed.

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QUESTIONS AND DISCUSSION

(John Lamb, DFO, Nanaimo): Have you ever looked at lake systems that have regular industrial inputs of sewage, or perhaps leaching from forest silvaculture practices, such as fertilization, to see if there's any change in the productivity of those lakes?

(Hyatt): Not as an explicit policy for assessment, but I've tried to find a bio-integrator for changes in trophic status in the lakes, something that would integrate over longer time spans than phytoplankton or fish.

I did a little pilot project where we looked at freshwater clam growth increments and analyzed those into a standardized growth index. It turns out that most of the lakes that we deal with have freshwater clams that live about 20 years. When you look back at the history, we can say that when we treat lakes, the trophic response is an unprecedented change in the lake's performance.

By extension, we've gone to Muriel Lake; we selected it as a little control lake for Kennedy Lake, which we were treating. Lo and behold, when we looked at the patterns for Muriel Lake, there was a major trophic response that the clams told us had occurred over about a five or six year period in Muriel Lake. My best guess right now, from looking at some additional control data from other lakes, is that what they're indexing there is a change in logging in the Muriel Lake watershed. Nutrients have come in and changed the trophic status unbeknownst to us, and then it's actually levelled out again. We don't have any direct programs to monitor this, but we do pick up on it on the occasional site.

(Lamb): But, you couldn't speculate whether that would be beneficial or not?

(Hyatt): It depends on the quality and the sort of constitution of the effluent. If you can put phosphorous and nitrogen into that effluent and can control it in the right ratios, it could deliver potentially the same benefits that we do by airplane. But you've got to distribute it evenly throughout the lake, and avoid problems with heavy metals, and other kinds of toxins.

(Gerry Taylor, MOE, Victoria): Are you aware of the selective piscicides that have been partially developed for stickleback?

(Hyatt): No, I don't know of any selective piscicides for those. I know that for squawfish there's a thing called Squax.

(Art Tautz): Alaska has looked at this quite extensively, because they're facing the same kind of situation that we're facing in our coastal lakes, with a lot of this biomass being tied up in sticklebacks.

(Hyatt): It's certainly true, except you've got to have a fair bit of information about where you're going to apply it. As I said, out of the 16 to 20 populations that we routinely look at, there are only around four of them that have limnetic sticklebacks. The other stickleback populations hug right into the literal zone. They never appear offshore, they don't eat zooplankton, they don't compete with sockeye.

(Tautz): Are they typically in the smaller lakes?

(Hyatt): No.

(Tautz): So if we have a large number of small lakes where we want to increase coho production, or sockeye, we're not going to be faced with stickleback problems?

(Hyatt): Oh, you will. I mean, they'll be just as big a problem in small lakes as they are in the big lakes.

(Tautz): Because there are an awful lot of coastal lakes with very short outlets to the ocean, where, if they were to be treated you would have very little downstream effects on other populations of fish, and it might be very worthwhile looking at?

(Hyatt): Yes.

(Tautz): Particularly from a benefit/cost point of view. It is less than your fertilization program, and in fact, one treatment might buy ten years of production before reinvasion, or whatever, as is our experience in many of our Interior lakes in British Columbia.

(Hyatt): If there was a selective piscicide for sticklebacks, there would be four lakes that I would know the benefit/cost might be pretty good.

(Tautz): I think this is an area that perhaps the federal government should be pursuing. We have an active provincial program, or have had, which is very low profile at the present time.

We have 150 lakes under management by chemical rehabilitation that account for a larger portion of our inland fisheries in the Interior, so why not coastal?

(Hyatt): I agree.

COHO COLONIZATION OF INACCESSIBLE HEADWATER HABITATS IN THE QUINSAM RIVER WATERSHED

Jim Van Tine
Stock Enhancement Officer
Quinsam Hatchery

I'm going to describe a coho colonization program we've had in place at Quinsam hatchery since 1977. This follows along with what Peter Pearse (in the Commission Report on Pacific Fisheries Policy, 1982) recommends as a semi-natural or a "soft" enhancement technique. The concept isn't new, the Americans have done it for years, but the fact that we've evaluated it is new.

I will briefly go over the program of what we do, how it evolved, then I'll discuss it in more detail and give you some of the results.

The Quinsam hatchery was designed and built with an incubation capacity of 20 million eggs, of which 4 million-are specifically designed for coho fry outplanting. These unfed fry would be from surplus hatchery adults and would be planted in rivers above obstructions. Fishways to alleviate these obstructions had already been ruled out because of their high cost. So Fred Fraser (DFO Stock Management) and the fishery officers from the Campbell River office identified approximately 100 miles of suitable habitat in the Quinsam River, Bear, Salmon and Adam Rivers and Pye Creek and it was estimated that these systems could produce up to 60,000 adults from this method.

But, before we could get the coho colonization program implemented, the newly-formed Transplant Committee cancelled all outplanting. They were concerned with genetics and the indiscriminate spread of disease. Fortunately, this did not prevent us from working within the hatchery watershed. Portions of the Quinsam River discharge is diverted into the Campbell system for hydro generation, thus adding to the low summer flows and high temperatures in the Quinsam.

We were originally going to plant fry into the river in the spring, but since we felt that the hatchery offered a better summer environment for the fish, we decided to keep them at the hatchery until the heat of the summer was over or until we needed the ponds for adult holding, and then transplant the fish out. So this gives us roughly 5 - 10 gram fingerlings to transplant out. There is another advantage to raising the fish and that is they can be easily marked with a coded-wire tag before they are outplanted.

Each spring following overwintering, as these outplants migrate down the river, we enumerate them at our counting fence above the hatchery.

The colonization coho can be distinguished because they have the missing adipose fin (clipped prior to release), and because a portion of them are coded-wire tagged. We can assess their contribution in various fisheries and we can assess their return to the river.

The hydro diversion on the Quinsam River marks the upstream limit of our planting for now. The area is accessible to anadromous fish up to a point known as the Grouse Nest. There are some cataracts and falls which could possibly block fish movement during low flows, so we've actually started our planting there. It's a stretch of river that's not particularly suited to coho; it's fairly fast and there is a lot of limestone and bedrock and shale that the water flows over. Then comes lower Quinsam Lake, which has pretty good reaches for coho, then we have the obstruction further upstream; another section above that which is basically a better steelhead area, a two to four percent gradient or something like that. Then we have Middle Quinsam Lake which is an area we plant into, then Long Lake, No Name Lake, then a little section of Quinsam River up to the diversion which we don't plant too many coho. That is a prime cutthroat spawning area. The last little area we use we call Flume Lake. It is an excellent coho habitat.

Our strategy has actually evolved over the last six years. Originally, we trucked the fish up, but of course we had only from three to five access points, so we used to dump 40, 50, 60, 80,000 fish from a bridge or something. We got results though.

For the last few years, we've been utilizing a helicopter. For the last two of those years, we used just your basic 100 gallon Hawkins-Power firefighting bucket. We'd load 5,000 fish into a 100 gallon bucket and arbitrarily dump 5,000 fish every quarter mile.

Last year, we used the transport tank designed by the Fish and Wildlife Branch. It has 10 compartments. We put 1,000 fish in each compartment and we're able to drop, in theory, 1,000 fish every 100 yards. The other advantage to this tank is that it worked on a 100-foot-long rope so it allowed the helicopter to stay above the trees but snaked the tank down to the river. We hypothesized that the more we can spread the fish out, the better survivals we are going to get. But this is as far as we're going to spread them out. One thousand fish every 100 yards is quite a lot of spreading.

Each year, we're identifying new areas and putting fish into those areas. I think we started only two years ago putting fish into Flume Lake and Long Lake, because we weren't even convinced the water flows out of those lakes all year, but it does, barely, during the out migration time there is adequate water. And they, incidentally, have been pretty good areas. The only new habitat I think we can explore now is above the diversion. And before we utilize that area, we have to have some way of ensuring the fish don't go down the flume and over into the Campbell system and through the generator, so we need some kind of a thing to divert the fish away from the spill dam and down the river. There are a few more miles of habitat if we can come up with something like that.

As well as planting fish in new habitat, we've stopped planting fish in some of the habitat that we determined wasn't so suitable. Between Middle Quinsam Lake and the falls, we said that's really too steep for coho, so we keep that exclusively for steelhead. We don't put any coho in the Iron River, that's exclusively for steelhead as well.

Each year, we plant out about 250,000 coho smolts that range from 5 to 10 grams. They are released to about 17.5 km of river and five lakes. This is done usually around mid-September. For the last three years, we've also outplanted 30,000 steelhead fingerlings, and they're the same size, 5 to 10 grams. Normally, we just mix them with the coho and dump them out as we go. But as I have already mentioned, we have identified some habitat that is more suitable for steelhead, so we take a couple of trips up with the helicopter and plant just steelhead in these more desirable areas.

Unfortunately, the steelhead data are not as complete as the coho data. I just wanted you to know we do it. There is some data gathered on it and if you want more information on that, I suggest you talk to Bob Hooton at the Fish and Wildlife Branch office in Nanaimo.

The outplanting program takes approximately two days to complete and we usually put about four people on it. The wages for the outplanting crew, fish food, and helicopter time are approximately $10,000 per year. So our costs to do this program is about $10,000/year; not including any costs associated with the hatchery. The hatchery was already there, I didn't get any extra budget or extra men or anything to do it. I just said that it cost $10,000. The evaluation of course is on top of that.

From 1977 - '82, we've averaged an outplant of 238,000 smolts. Those are going out in September. The next spring, in May, we've been counting them at our counting fence. From 1978 - '82, we've averaged almost 43,000 smolts out, which is a survival from plant to outmigration of 18.6 percent.

The total adult return for the first year was 8,800 fish; 1,183 escaped to the Quinsam River; 3,600 were caught by commercial fishermen in Canada and 3,600 were caught by sport fishermen in Canada and there was a small catch by the U.S. fishery as well. Assigning conservative values of $10 per commercial caught and $30 per sport caught fish gives us a benefit of $155,000 and that's on what I consider a $10,000 investment.

The next year's data, same number of fry, same average survival. This time the adult return was down slightly, to 10.4 percent, but it still gave us 6,000 adults back; still gave us 3,700 to the commercial fishery, which was about the same as the previous year, but the decline was in the sport catch. I don't really know why that is. It could be that the fish went to a different area, had a different migration route and weren't caught, or it could be that the head recovery awareness factor between the two years changed significantly. There was roughly the same escapement: 1,000 in one year and 1,185 the second. A little bit lower benefit this year of only about $76,000, but still a pretty impressive return for only about $10,000.

We've marked those fish every year but one. We went along for three or four years and people said you don't have to evaluate forever, stop. So I stopped, and lo and behold, we were bestowed a coal mine so we thought we'd better start marking again. We've missed one year of marking, but we will have this kind of data generated every year.

The confidence on our downstream numbers is pretty good, I think we're within about 20 percent either way, and as far as the information I got from the head recovery people, Ted Perry specifically, they have a whole committee working to try to establish what the confidence is in that data. They don't really know yet, all he would say is that it's the very best data Fisheries has ever had on catches.

One of the reasons we can do this coho program so easily is that the Quinsam hatchery has three large Burrows ponds for adult holding. They are vacant from the first of June to sometime in mid-September. We've got lots of nice, cool water there, so it gives us an ideal place to put the fry, rather than putting them out into the river where conditions wouldn't be as good.

We have been experimenting with releasing steelhead in some of the lakes too, and they've been differently clipped just to see if we can determine how much they might use that environment.

When you're ready for an outplant, you simply crowd the fish into the corner of a pond, put the intake down and it sucks them up real nice. It doesn't hurt them either.

The helicopter comes in and drops one tank off and picks up another one, and he's on his way. Our longest round trip is about 25 minutes. When he gets to the area, he lowers the bucket right down, right into the water if he wants, and dumps the fish.

There are some problems with this outplanting strategy. We have to decide what we're going to do about genetics. Are we going to use only native stocks? If we are, we're in trouble because a lot of creeks don't have native stocks anymore. Are we going to mix stocks? Are we going to take a good stock from here and a good stock from there and mix the two together and use those eggs, or that genetic pool, to transplant into a barren stream? Or are we going to take the easy way out and just use surplus hatchery fish? I'm not going to answer that question, but somebody has to.

We also have to deal with the interactions with the trout species. I think cutthroat is probably the most significant in that respect.

And where do we do coho colonization? How do we know where to do it? I think we have to have proper inventories. We've taken six years to get to this position. But I know if we had a proper inventory, the fisheries management people could come right to me and say, "we want this many fish here, and this many fish here and here" and I could just go and do it. It wouldn't be as interesting and exciting, but it's probably the proper way to do it.

I know that with the tools that Chamberlain and Tutty have been developing with the prereconnaissance SHIP thing that fishery managers now have the opportunity to do exactly that. They can look at areas, define areas that should have coho, that should have steelhead, and we can very simply get on with the job.

Basically, in the Quinsam watershed we've colonized 17 km of river and a few little swamps and lakes and on the average, I'd say we could produce 75,000 adults. It might cost $10,000--that's my conservative figure--and on average generate a benefit of about $100,000, so I think we should get on with the job and take the bull by the horns.

QUESTIONS AND DISCUSSION

(Don McQuarrie, DFO, Vancouver): You mentioned the loading rates for stocking your fry out in the river. What loading rate did you have for the lakes?

And related to that; could you tell if there was a difference in size between the smolts produced in the lake and the smolts produced in the river?

(Van Tine): We have no way of telling if there's a differential growth. As a matter of fact, we don't even know that the smolts that we put in the lakes stay in the lake. We know that one year we planted the area between the falls and Middle Quinsam Lake with 15,000 coho smolts, and we looked all over there and we couldn't find one.

So, we thought we might as well save them the trouble, we won't put them in there. We don't even know what goes on up there. There's just so much information that could be gathered. I could keep three or four research scientists busy up there for the next ten years, I think.

As for the lakes, we're putting in anywhere from 5,000 to 30,000 fish which isn't a very heavy stocking. At the bottom end of that swamp, in Flume Lake that I showed you, it would be a really good place to put some coho, but it seems to be the only area that there's a concentration of cutthroat.

(James Buell): The 18.6 percent fingerling to smolt survival; is that what you figure their survival is, from what you put in, to what comes down the river as out-migrates to the ocean?

(Van Tine): Yes, that's an average over the six years that we've done it.

(Buell): What do you think the major source of mortality is? I know there's a pretty active sport fishery there at lower Quinsam Lake, and so on. Do you think any of them get caught in the sport fishery?

(Van Tine): I don't really know. I've always thought that the major loss was associated with the fact that these are hatchery fish. We've got them and we're feeding them, and they don't even have to look after themselves. When they go out there they have to adapt to eating natural food.

(Buell): Are there Dolly Varden in those lakes?

(Van Tine): I think there's mostly cutthroat. I don't know if there are any Dollys up there, or not. But, there's rainbow and cutthroat.

(Buell): The lower barrier that you showed us; I agree with you that it is probably passable at some flows, but, if you look at the bedrock slides in that same vicinity, some of those appeared like they would be velocity barriers. They went on for a long way, some of them were a couple of hundred meters of continuous slide.

(Van Tine): Yes, we've never found coho above this. That's why we haven't transplanted above that big one.

We dropped down because we felt that they weren't getting beyond that. We'd never seen them above that, so we actually dropped our planting back a little bit so there could be an overlap there.

The other thing that we don't know about is how many of these fish drop back a long ways, and do compete with the natural fish lower down. You have to appreciate that this type of study is just something that I did on the side. I spent maybe four or five days a year doing this program, and there's a lot of information that's slipped by. It's not because we didn't think about gathering it, we just don't have that much time to spend on it.

(Del Skeesick, USDA, Forest Service): I feel like a blind dog in a sausage shop, because there's so many questions I could ask you about your operation. This is much the same thing that we were doing when I worked for the Oregon Fish Commission about ten years ago.

One thing that comes to my mind; you mentioned you did have some vehicle access above the hatchery. Did you consider moving some adults up and allowing them to go up and spawn naturally?

This is one thing that we found to be very effective in a number of watersheds down there.

(Van Tine): We thought about that. It would be interesting to stop this coho colonization now, give it a couple of years to dry out, and then start putting adults up there and compare the differences. But, there is a number of problems in terms of evaluation. Number one, we wouldn't have those fish marked, so we wouldn't know whether it was a natural population from below the falls or above the falls.

Number two, it still hasn't got us around the problem of low flow and high temperatures in the summer time. Besides, this is a little bit more high profile. You know, you've got helicopters buzzing around.

(Skeesick): If it's any consolation, we learned how to use a helicopter down there in the high lakes about four years ago. We were using a Bell 212, and we were able to haul enough fish to stock 30 lakes at a time.

I was curious about the Fish and Wildlife tank you mentioned; is that your Fish and Wildlife tank, or is it a stateside Fish and Wildlife tank?

(Van Tine): That's one that the local people here have developed for outplanting steelhead where they really want to. The prime idea is to place them as scattered as you can. They're not very big compartments, I think they're only four gallons, or something, each.

(Skeesick): I would like to find a person I could contact to take a look at it.

(Van Tine): You'll find this tank usually at the Abbotsford trout hatchery, although it travels all over B.C., I assure you. We're actually looking at getting another tank built now, because I think 1,000 for coho is a little bit of an overkill.

We're going to get one designed with three compartments. It's a cylinder type thing with three compartments you can dump. That would be just right for us, 3,000 fish.

(Art Tautz, MOE, Victoria): Kim, I wonder if you could maybe just spend five or ten minutes reviewing what you know of the coho colonization in Alaska.

It has been, as far as I know, a fairly active program in Alaska, and is probably a much bigger program than we're considering at this point.

(Kim Hyatt, FRB, Nanaimo): I've heard Jeff Koenings speak a couple of times about their Alaskan work. Essentially, they have an integrated program that looks at habitat management via lake enrichment, outplants and transplants. They deal not only with lake production of sockeye, but also with outplanting coho from production hatcheries as well.

Their attack has been to identify a series of experimental systems, usually within a single watershed which has a series of small lakes where they can count adults in and count smolts out. They outplant hatchery fish at a particular density into barren lakes and assess the growth and survival at that density. Then they up the density by a notch and assess it some more. They keep upping it until they see how much the lake system can bear in terms of the carrying capacity with respect to a particular size of smolt being produced, and also with respect to a given level of within-lake survival.

What they've found from some of the experimental manipulations, is that as they increase density, the smolt size begins to drop. In association with that, the within-lake survival begins to drop as well.

What they have done then is to look at increasing and restoring some of that size and survival balance by going in and enriching the habitats.

They use lake fertilization, layered on top of the outplant strategy. The result as indicated by the one experimental comparison that I think they've completed, is that, yes, they can boost the smolt size back up again as it's dropped, and the associated within-lake survival goes back up as well.

Their procedure has been to approach it very systematically, to look first at what the habitat can carry without manipulation, and then to start some very incremental types of manipulation, to see how they might optimize their overall planting and habitat management strategies.

They're doing the same thing with sockeye.

What they found out about outplanting sockeye and coho together, is that sockeye are a whole lot better at harvesting zooplankton than are coho. In the absence of sockeye, the coho outplants will use the offshore waters in some of these small lakes, and will gobble down zooplankton, as long as the sizes of the organisms available in the upper water column are above roughly 1,000 microns, or a millimeter. You've got to have zooplankton a millimeter or bigger to really satisfy coho very well.

If you put sockeye there, they would crunch everything down to the point where zooplankton averages around 500 microns, half a millimeter. The coho all go back inshore, and certainly can't complete in terms of occupation of the offshore waters. The survivals they're getting are very comparable to the kinds of figures you're getting from fry outplant to smolts-out. They're looking to use lake enrichment to increase that survival by another six to eight percentage points.

In the future, I think what we can expect to see is that the Alaskans, by virtue of this rather systematic approach, will generate a lot of information that we will find of great use here.

Paired with this sort of systematic appraisal of what the carrying capacity is, they also have a habitat inventory program. They have a mobile crew a lot like the Lake Enrichment Program's research crew; it assesses the distribution of receiving waters in south-eastern Alaska in particular, and looks at the abundance of food organisms, gets some kind of reading on which non-anadromous species of fish might be present. That process begins to rank habitats with respect to the desirability for outplanting. I think they also look at the manageability question of where the harvest can be taken when adult fish come back, and overall, try to optimize production benefits. We should be doing this within British Columbia; I don't think we've managed to get our act together in this respect yet.

ENHANCEMENT OF KOKANEE SHORE SPAWNING SITES IN OKANAGAN LAKE, BRITISH COLUMBIA

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INTRODUCTION

The Okanagan Valley in south-central British Columbia is a very scenic area with an economy based on fruit production, forestry and tourism. The latter is increasing in importance, and sports fishing is a major tourist draw. Kokanee (land locked sockeye salmon Oncorhynchus nerka), are the major sports fish in Okanagan Lake. In 1980, over 200,000 were caught with an average success of just over one fish per rod hour, and fishing pressure is expected to triple in the next 25 years (Bull, unpublished). Juvenile kokanee are also a major forage fish for a limited population of trophy size rainbow trout. Fishing success is not uniform over the lake, but seems to be best adjacent to areas where kokanee spawn.

Okanagan Lake kokanee can be divided into two sub-populations based on spawning habit. The stream spawners face serious habitat losses due to domestic and irrigation water demands, stream channelling and flood protection. The lake shore spawners do not face the same habitat problems, but the lake level is drawn down through the winter in preparation for spring runoff, and eggs and alevins may be lost to desiccation or freezing.

During the late 1970s, it appeared that shore spawning habitat was fully utilized by kokanee and future population growth or even maintenance would require improved spawning. Therefore, in the early 1980s, three studies were undertaken to gather information on water and substrate characteristics required for successful spawning.

EGG AND ALEVIN DISTRIBUTION IN RELATION TO WATER AND GRAVEL DEPTH

In 1981, preferred water depth and spawning substrate, as well as time of hatching, was examined on several productive shore spawning sites of both gravel and cobble. Transects of 0.5 metre grids perpendicular to the beach were excavated and the eggs and alevins in each square were captured by a suction pump and collected in a bucket. The transects extended six metres out into the lake and were sampled by divers. The sites were sampled a number of times throughout the incubation period to determine the time of hatching and emergence, and also the movement of submergent alevins.

Spawning occurred mostly in water shallower than 60 cm with the greatest number in 10 - 30 cm of water. By February 19, 1981, all eggs had hatched, and while most eggs were found an average of 20 cm under the gravel, most alevins were found 30 cm deep in the gravel. A one-metre barrier screen was buried parallel to the beach prior to hatching and the area behind the screen and a control area immediately adjacent, were excavated. Almost five times as many alevins were found in the screened area compared to the unscreened. These results indicate a strong downward and lakeward migration of submergent alevins following hatching. Incubation mortalities could be reduced by maintaining constant water levels during the egg stage, then manipulating water levels after mid-February when the alevins are able to move in order to escape desiccation (Matthews, unpublished).

QUALITIES OF SHORE SPAWNING SUBSTRATE

Some parameters of spawning substrate were examined by sampling both traditional spawning beaches and several sites with no spawning history for substrate composition and oxygen. A measured amount of substrate from each site was taken to the lab for screening and sorting and subsurface dissolved oxygen was sampled using a large syringe. Spawning material had a low percentage (less than 10 percent of fines through a number 4 sieve screen) and a high percentage of dissolved oxygen (10 - 12 ppm) while the unused substrate had up to 40 percent fines and dissolved oxygen of less than 6 ppm. There does not appear to be a maximum particle size, as spawning has been observed on material as large as three metres in diameter, but more commonly over angular substrate 10 - 30 cm in diameter (Houston, unpublished).

ENHANCEABILITY OF SHORE SPAWNING

Preferred spawning substrates were investigated by introducing material onto a shallow bedrock shelf with no previous kokanee spawning history. Two sizes of rock were placed to a depth of 40 cm, one of clean gravel (2 inches minus) and the other of angular cobble, 10 - 30 cm in diameter. Kokanee were observed spawning on both introduced substrates but showed a preference for the gravel, apparently not discriminating between the introduced and the adjacent natural sites (Houston, unpublished). Following an inventory of traditional kokanee spawning areas, six criteria were identified for ranking and priorizing potential enhancement sites, namely (Jantz, unpublished): type of existing substrate; wind protection; proximity to material; present use by fish; machinery access; and size of site.

Site-specific costs for recommended treatments and land tenure problems must be addressed before proceeding with the enhancement of the most promising sites.

CONCLUSIONS

In Okanagan lake, kokanee spawn successfully along the shoreline even in areas lacking upwelling water. A wide variety of substrate size and shape may be selected, but must be free of fines and well supplied with oxygen. Spawning occurs in shallow water and while stable lake water level is desirable during egg incubation, it is less critical following hatching because the alevins can migrate lakeward through the gravels.

If quality and site characteristics are met, kokanee will also spawn in a variety of introduced substrates and successful shore spawning can be increased.

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QUESTIONS AND DISCUSSION

(Dave Bustard, Biological Consultant): Although you found that kokanee don't require upwelling for spawning, were you able to monitor these sites that didn't have upwelling and find that kokanee were successful in these, to emergence?

(Harris): In that one site, there was no possibility of any upwelling water there. It seemed that the water that was contained in the gravel, coupled with a sufficient amount of wave action, maintained adequate oxygen levels. There can be, however, a trade-off point where there's just too much wave action, and constant exposure.

But, yes, it does not appear that there is a requirement for upwelling water.

TERRESTRIAL VEGETATION IN THE DRAWDOWN ZONE OF FLOOD CONTROL RESERVOIRS IN OREGON

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INTRODUCTION

One of the inherent characteristics of a water storage reservoir is that during the drawdown phase, large areas of exposed soil are evident. Wave wash and wind erosion keep this soil in motion and continue to move it toward lower levels of the reservoir, leaving step-cutbanks and additional turbidity in the water. When these reservoirs were built, all of the stabilizing vegetation was deliberately removed, because of its effect on water surface usage or upon water quality in the reservoir itself. As a consequence, there is very little benefit derived from these exposed areas during the period of time when the soil is exposed to the air and sun. However, recent observations have indicated that there may be certain terrestrial plant species that are able to withstand long periods of inundation and grow during the relatively short exposure periods. In many cases, the limiting factor appears to be reproduction.

An examination of the species of plants that are now found in the reservoir drawdown zones, and some of their characteristics, leads us to believe that there are at least five separate benefits that can be derived from having live terrestrial vegetation in the drawdown zones (Table 1).

Table 1. Benefits of Terrestrial Vegetation in Reservoir Drawdown Zones

1. Stabilize reservoir banks.
2. Increase wildlife use.
3. Provide physical structure for fish habitat.
4. Increase fish production.
5. Improve reservoir appearance.

Stabilizing the reservoir banks is beneficial from the standpoint of reducing the water-borne sediment that is picked up daily as the wind-induced waves pound against the shorelines. By creating some stabilizing force, not only is the soil within the reservoir drawdown zone kept in place, but also steep banks just above the reservoir high pool are also kept from failing and falling into the reservoir. Increased bank stability above pool area reduces the influx of woody debris that floats to the windward shore and gouges the banks.

During the exposed time periods, terrestrial vegetation is available for wildlife uses. Deer and elk feed on the new growing plant material, as well as use it for winter browse in certain areas. Larger woody material is utilized by beaver, and certain species of sedges, grasses, and forbes are utilized by waterfowl.

The larger material becomes a significant item for fish habitat, by providing structure. Certain species of fish are known to accumulate around down logs, brush piles, etc., and live, large, bushy plants serve the same purpose.

The organic matter produced during the drawdone phase is available as the reservoir begins to flood again in the spring. This matter is quickly utilized by invertebrates in the reservoir bottom, and in the water column, to begin the new cycle of animal growth. These invertebrates contribute to the food chain of fish and other aquatic vertebrates.

A reservoir with exposed banks is certainly the least appealing body of water that we have. One reason it is unappealing is because it is a large expanse of one visual type. Terrestrial vegetation growing in the drawdown zone can add color, structure, and form to the landscape. Each of the characters is important in providing a scenic diversity and an increase in the aesthetic characteristics of the area. The stabilized banks also allow for greater recreational use by covering the silts and clays with living vegetation.

BACKGROUND

Beginning in 1950, large-scale efforts to construct flood control dams to protect the communities and lands in the Willamette Valley began (Figure 1). By the mid-1970s, a total of 13 major dams for flood control, power production, and/or irrigation had been completed. When all of these reservoirs are filled, 35,000 acres of land are inundated. When all of these reservoirs are reduced to low pool in the late fall, there are 21,000 acres of exposed reservoir banks (Table 2).

Table 2. Willamette Basin Reservoirs

Reservoirs	Full Pool	Low Pool	Exposed Acres
Henry Hagg[1]	1,120	580	540
Detroit	3,580	1,450	2,130
Green Peter	3,610	2,070	1,540
Foster	1,195	895	300
Blue River	1,420	130	1,290
Cougar	1,280	635	645
Fern Ridge	9,335	1,500	7,835
Fall Creek	1,880	425	1,455
Dexter	1,025	960	65
Lookout Point	4,360	2,250	2,110
Hills Creek	2,710	1,550	1,160
Dorena	1,840	500	1,340
Cottage Grove	1,160	295	865
	34,515	13,240	21,275

[1] Irrigation reservoir does not fluctuate in winter.

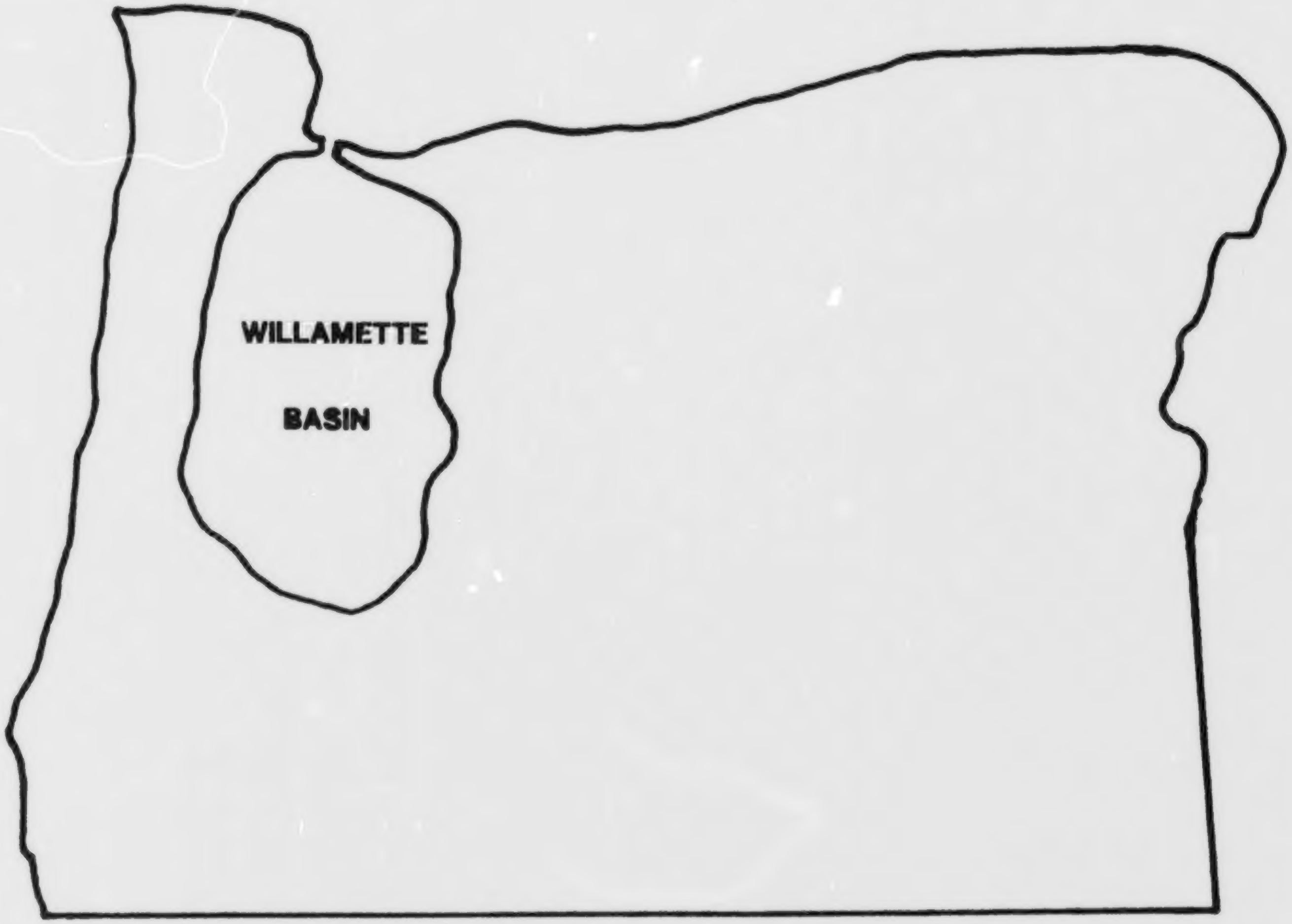
WILLAMETTE
BASIN

Figure 1 WILLAMETTE BASIN, OREGON

These reservoirs are filled in the early spring and maintained at high pool for most of the summer. They are evacuated during the fall, and are kept at low pool levels during the wintertime, except when they need to ameliorate flood flows (Figure 2). There is a short period in the spring, and again a period in the fall, when the terrestrial vegetation is exposed while temperatures are adequate for significant growth of the vegetation to occur.

EARLY TESTING

Beginning in 1970, two U.S. Department of Agriculture agencies, the Soil Conservation Service and the USDA Forest Service, cooperated to determine if certain species of plants could be expected to grow in the flood control reservoir drawdown areas. Initially, 20 species of grasses, forbes, sedges, and trees were tried at various plantation sites on Blue River Reservoir, Lane County, Oregon. The success of the trials was monitored until about 1977, after which the project was abandoned. The project was rediscovered in 1981, and it was obvious that there were at least three species that had survived very well, and had characteristics that would be usable for providing one or more of the previously discussed benefits. These three species were: bald cypress (Taxodium distichum), Columbia sedge (Carex aperta), and the common slough sedge (Carex obnuptal) (Skeesick, 1983).

Bald Cypress

The initial trials included a single row of bald cypress planted from the bank to a depth of -51 feet. These trees survived very well (approximately 80 percent). Those trees growing in less than 10 feet of water are doing very well and are currently exposed, even at high pool. At deeper depths with less exposure period, the trees have survived well, but have grown at a lesser rate (Figure 3).

Bald cypress is a tree found in the Mississippi Valley, from southern Illinois southward to the gulf of Mexico. Its range extends from Texas eastward to North Carolina. It is a deciduous coniferous tree that has a brushy growth form in the young stages, but becomes a large tree species as it matures. It is known to reach heights of 120 feet. It is characteristically strong-rooted, with considerable blowdown resistance. It is very water-tolerant, and because it is deciduous, it is also able to withstand the cold quite well. In the reservoir drawdown zone, bald cypress should provide mass and strength to absorb wave action, should provide physical habitat for fish, and should provide excellent visual diversity.

Columbia Sedge

The Columbia sedge was initially planted as two rows of sedge sod plugs planted at a 2-foot x 2-foot interval in a row from zero to -50 feet. In the ensuing 11 years, the sedge spread to form a solid row approximately four feet wide extending from the shoreline to the maximum depth to which it had been planted. The spread rate is one to two inches per year.

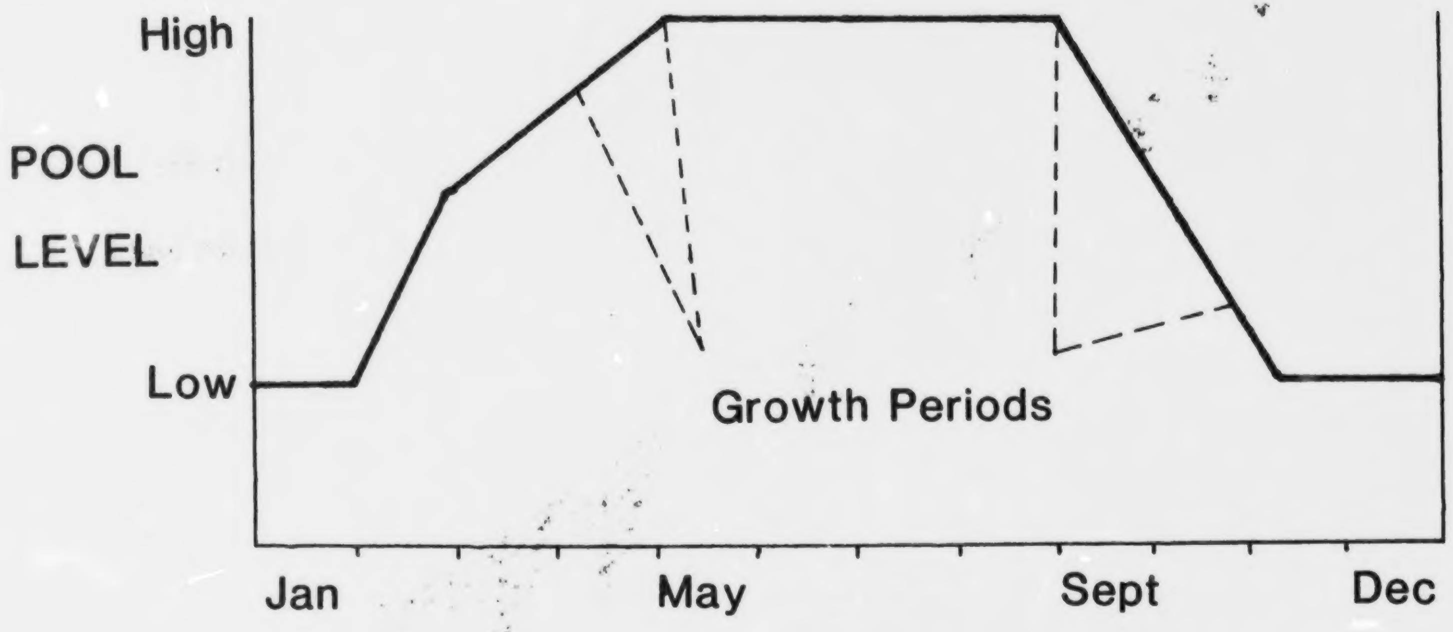

Figure 2 TYPICAL FLOOD CONTROL RESERVOIR WATER LEVEL MAMAGEMENT SCHEME

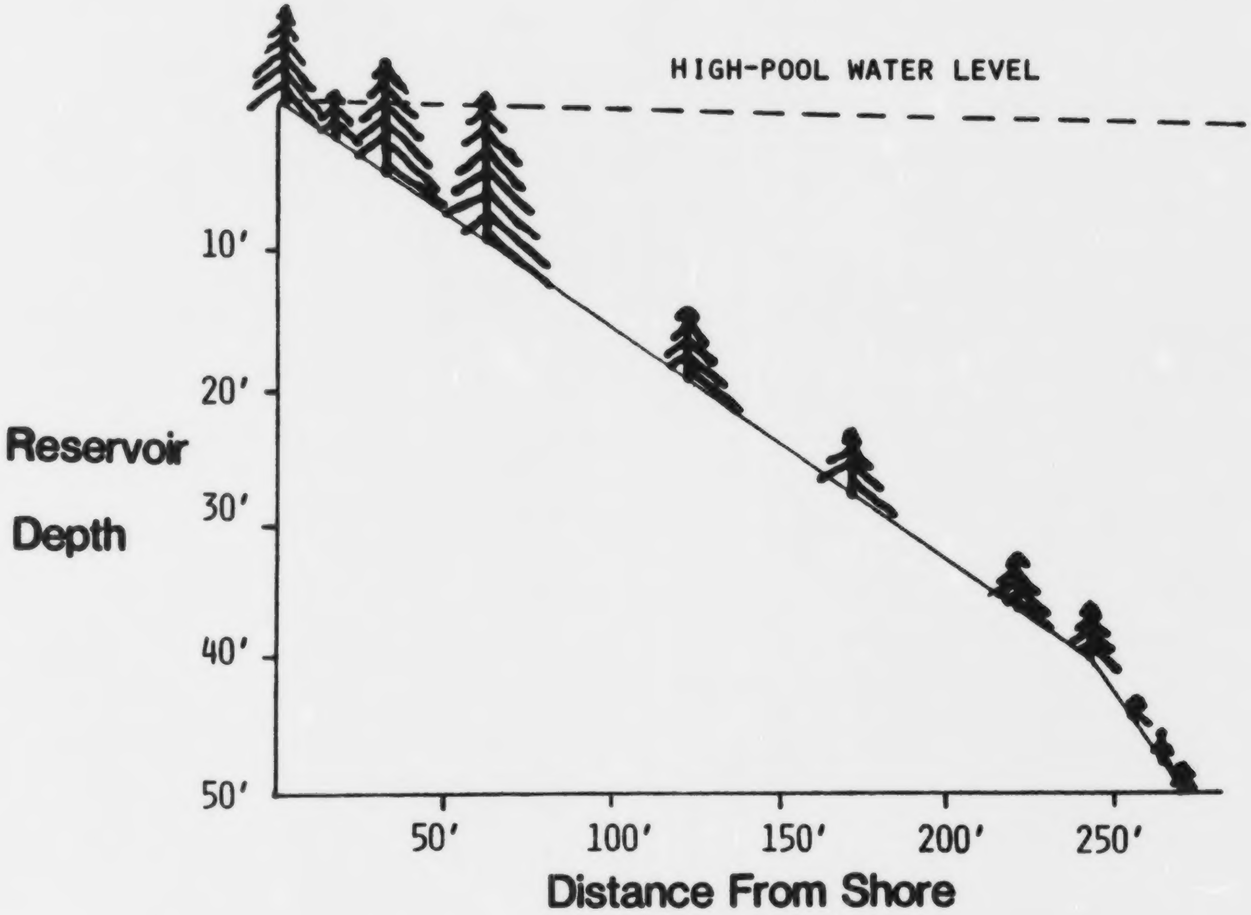

FIGURE 3- BALDCYPRESS (TAXODIUM DISTICHUM) HEIGHT DISTRIBUTION IN BLUE RIVER RESERVOIR, 1983

Columbia sedge is a densely rooted plant that grows while exposed, seeds, and then dies back with the first heavy frosts. It grows rapidly in the spring before inundation, and then goes through a period of suspended growth while the plants are covered with water. By fall, it reaches a standing crop of approximately 7,000 pounds dry weight per acre. At Fish Lake, a natural ephemeral lake in the Cascade Mountains, the newly emergent sedge is grazed by mule deer and after the lake dries up, the USDA Forest Service pastures a string of pack mules on the sedge-covered lake bottom.

The sedge is expected to provide significant bank erosion protection, generate deer and elk food during the early spring and late summer, and provide a significant quantity of organic matter for fish production. Its verdant color improves the scenic diversity of the reservoir banks in the fall.

Slough Sedge

The slough sedge was planted as plugs similar to the Columbia sedge in the original trials. It has survived very well to a depth of approximately 15 feet. Beyond that, the survival was disjunct, but there are clumps growing to a depth of -25 feet. This species has spread much more rapidly in the shallow zone, and the original trials are diffuse, but the amount of plant material there indicates an excellent spreading rate. The slough sedge spreads by stolons, and can capture a new area at the perimeter of the plant at the rate of about eight inches per year. It is winter-active, growing some in the spring, is inactive during the inundation period, and then grows rapidly again in the early fall. Deer and elk are known to use it during the summer growth period, and because it is winter-active and stands upright, it is available to elk for winter food, even during periods of significant snow. It is known to have a late summer standing biomass of over 7,000 pounds per acre.

The slough sedge has an especially dense, fibrous root mat, so it can be used for bank stabilization, for deer and elk feed, for production of organic matter for fish feed, and also will aid materially in developing the visual diversity of the reservoir areas.

NATURALLY-OCCURRING VEGETATION

Concurrently with the rediscovery of the vegetative trials, two species of willow were noted inhabiting the reservoir areas. These were the coyote willow (Salix exigua) and the Pacific willow (Salix lasiandia). Both species are apparently from natural sources.

Coyote Willow

The coyote willow is a stoleniferous spreading willow growing on sandy, gravelly substrate and reaching a height of approximately seven feet. It grows in large stands, but is not very dense. Elk utilize this species heavily.

The primary purposes of this willow would be for deer and elk browse, and for stabilizing coarse, sandy, gravelly banks. It should also provide spawning and rearing habitat for warm-water fish species, such as largemouth bass.

Pacific Willow

The Pacific willow grows in dense clumps and is known to reach a height of 15 feet. It apparently does not spread by roots, but will grow from cuttings. It appears to be more tolerant of wet soils and grows well to a depth of -40 feet. The large size and bushy nature adds visual diversity to the exposed reservoir banks.

This species should provide deer and elk browse in its younger stages, and as it matures, will add the structure, which is beneficial to warm-water fish species, and certainly the organic matter produced will contribute to the aquatic insect and aquatic invertebrate food base in the reservoir.

RECENT TESTS

As a consequence of discoveries of the vegetation growing in Blue River Reservoir, it was concluded that reproduction was the limiting factor for several species. A number of trials were begun, to determine the methodology for successfully planting various species, and to determine the capabilities of the species, as well as the methods for reproducing them.

Bald Cypress

Bald cypress tests included developing the techniques for producing the plant, as well as determining its tolerance to soil types, depths, and aspects.

Cuttings from the existing trees were treated with Indolbutryic acid and Captan, a fungicide, just prior to spring bud-break. The cuttings were stuck in a standard potting mix and kept in a mist chamber, where they were provided with a fine spray at regular intervals. They were treated regularly with a variety of common fungicides. Survival from cuttings to dormancy the succeeding fall was 53 percent. These young trees were planted in February in Hills Creek Reservoir, near Oakridge, Oregon, to a depth of -30 feet, and have subsequently gone through one period of inundation. First-year survival is approximately 80 percent, indicating that these plants have the capability of surviving well in Hills Creek Reservoir.

Several thousand yearling bare-root cypress have been out-planted this winter to test tolerance to soil type, exposure and depth. Bud-burst was occurring just prior to reservoir filling, so survival will not be known until drawdown occurs this fall.

Willows

Willow cuttings have been planted at numerous places in the reservoirs, to test survival versus depth for various species. One group of Pacific willow planted to a depth of -30 feet in Hills Creek Reservoir showed significant survival from zero to -20 feet, but very poor survival beyond the -20-foot depth. Current trials are to preroot some of the willows to provide a healthier plant to make use of the early fall growing season.

Sedge

Attempts to spread sedge have concentrated on using chunks of sod, because there is not a significant quantity of sedge seed available, nor do we currently have the technology to cause it to germinate. Initial test plantings of Columbia sedge indicate a first-year survival rate of approximately 75 percent after one period of inundation. Numerous additional out-plantings were accomplished this year, and have survived winter, but have not had a period of inundation to test their survivability. Deer and elk have already been utilizing the new plants at several of the plantations.

COSTS

As would be expected, the cost of planting an acre depends partly on the density of the plantings, as well as the cost of producing the material to be planted (Table 3).

Table 3. Terrestrial Vegetation Planting Costs

	Costs per acre
Cypress	
8' x 8' spacing	295
10' x 10'	188
Willows	
8' x 8' spacing (fresh)	239
10' x 10'	154
8' x 8' spacing (rooted)	357
10' x 10'	225
Sedge	
2' x 2' sod	1,228
5' x 5'	260
10' x 10'	91

CONSTRAINTS

Concerns expressed by various people deal with the introduction of nutrients to reservoirs, the restriction of boating traffic, and the introduction of exotic species.

The introduction of terrestrial plant species to the drawdown zone of a reservoir certainly will have some effect upon the nutrient balances in the reservoir during the high pool stage. As noted earlier, a fully developed stand of sedge can generate as high as 7,000 pounds per acre per year of organic matter. It is expected that most of this organic matter will be cycled through the zooplankton and fish, and will be tied up before it leaves the reservoir. Also, the extremely high flushing rate of these reservoirs would not allow for any significant accumulation of nutrients in the reservoir area. After 20 years of leaching the available nutrients from the soils, these reservoirs are a nutrient-poor environment. Adding some nutrients from the terrestrial plants will certainly have a positive effect on the reservoir's productivity. Since only about 25 percent of the total reservoir area will produce any terrestrial vegetation, it is not likely the production will create a nuisance either in the reservoir or downstream.

Tall growing species, such as willows and bald cypress, may indeed restrict boating traffic. However, it is expected that these species will only be planted in the shallower reservoir zones, where boating is inherently dangerous. Thus, although it could be considered that the vegetation is restricting boat traffic, it may also be considered that they are helping guide boat traffic away from hazardous areas. At most, approximately 10,000 acres will be treated and most of that will be sedge, which does not interfere with boating.

Introduction of any biotic species outside its normal range, where it is not in balance with its typical competitors, is a matter of concern. Introduction of those species must be with full consideration of their potential escape to effect other surrounding areas. In the case of bald cypress, the plant appears poorly competitive at other than a very wet site, so it is not anticipated that it will provide any competition for local upland species. It has been distributed to many parts of the nation (Whitlow and Harris, 1979), and to our knowledge, so far has not generated any problems in any of the areas where it has been introduced.

FUTURE OUTLOOK

The entire concept of introducing terrestrial plant species to reservoir drawdown zones is quite new, and our capabilities are certainly in their infancy. The concept has been started, and the knowledge has begun to accrue, but certainly we have not yet reached the inflection point on the learning curve. Certainly, as more people get involved and begin to observe what is happening in various reservoirs with various drawdown regimes, many more species of plants will be identified, and their uses and limitations will become known. Only then will we be able to write prescriptions for treatment of the reservoir drawdown zones from a knowledge base rather than from an experimental base.

Some activities that are expected for the future are to improve the techniques for establishing the existing species. This will include determining the tolerances of the species to soil types, aspects, and inundation periods, as well as developing the actual skills for planting them properly. A high priority item undoubtedly will be to determine methods for getting sedge to grow from seed. Doing so will allow plantings in areas that are inaccessible by other than helicopter or boats, and will allow planting large areas at a reduced cost.

Other investigations will undoubtedly seek out new species to match up with specific reservoir regimes. Certainly, as a minimum, there are many more species of willows that warrant trial.

LIMITATIONS

The primary limitations on establishing terrestrial vegetation in drawdown zones of reservoirs are lack of funds to begin actual accomplishments of projects, and a lack of understanding on the part of reservoir managers and land managers in general that we do now have technology that can be applied at this time, and that there are tangible benefits from such efforts.

One of our charges certainly must be to spread the word that yes, there are some things that we can do; yes, there are some benefits to be derived; and that yes, it is worthwhile to fund such a venture. Once the sales job has been accomplished, there is no doubt that planting terrestrial vegetation in reservoir drawdown zones will become a significant activity in the future, to the benefit of fish and wildlife habitat and production.

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QUESTIONS AND DISCUSSION
ON
ALL SESSION II PRESENTATIONS

(Ron Kistritz, Biological Consultant): The reservoirs you've described are about 20, 30 years old. Why, after that length of time, hasn't there been some more natural colonization going on? You've shown examples of some of it occurring, but you're undertaking projects where you're having to plant vegetation in these areas. If it's caused by the water level changes, how is that affecting the plants that you are planting?

(Skeesick): There are certain species of vegetation that are growing in some small isolated spots in the reservoir, but because the reservoir has such violently fluctuating habitat conditions, and because there's such immense soil movement on the banks, a lot of plants that would rely upon seeding as a way of getting established, are just not going to cut it. Those that will, move about by clumps, such as a rooted chunk of a sage that's either disturbed and drifts off, and sets down, or elk ripping out a chunk of root and dropping it someplace along the line, or pieces of these willow plants that may have come in by boat.

I think it's going to take a very serendipitous occurrence before vegetation really gets spread throughout these reservoirs. This may be a 100 year, or even more than a 100 year time frame to really get plants fully established, and then they may not be those that we can get the most productivity out of. They may only be those that have the greatest invasion capability. All we're trying to do is give the plants that opportunity to move in a manner that is not really typical of reproduction within a plant species.

(Brian Harris, MOE, Penticton): Most of your reservoirs are wet during the summer, during the growing period, is that correct?

(Skeesick): Yes, they're all full.

(Harris): Have you had any experience with plants that are growing in reservoirs that have actually drawn down in the growing period?

(Skeesick): Any time that we could have some drawdown in the summer, we'll get a hell of a lot faster growth, and more production than we will where drawdown doesn't start until the latter part of August. By the time you get into late August, early September, your growth potential is really beginning to drop rather precipitously, because your day length is shortening, your radiation is less.

(Harris): You don't find there's a problem with desiccation, or anything?

(Skeesick): I think we'll end up going probably to some different species. Fish Lake is a good case in point for you; that's a natural lake that fills in the spring with snow melt, then it goes dry in about the middle of July or the first of August. It's basically a sand bottom lake. By late summer, that sage out in there is dormant; it doesn't turn brown, but it's dormant. Its seeds ripen about the middle of September.

(Gerry Taylor, MOE, Victoria): I'd like to ask Jim Van Tine, are you going to write up, or is it written up, what you've given to us today?

The reason for asking is, of course, the Johnny Appleseed attitude that you've got. Obviously some of the survivals are quite high compared to some of the other projects that we've witnessed around the province, and I think it would be very useful to have the information out in a very simple form.

(Jim Van Tine, DFO, Campbell River): We've done a fairly extensive study up there, utilizing one of these job creation programs to move into the Quinsam Coal field a little bit more, to try and investigate that area; that will be coming out. There's already a rough draft that we put out for the public inquiry, and we're working on a technical report, which should be going to the printers shortly.

I'm not sure that that's really going to answer all the questions you had about coho colonization, but I think it will cover most of them.

(Taylor): I would like to encourage those people, other than protection and management biologists, particularly hatchery people, when they do have these kinds of things that they do get them out. This has been a real lack in our program, other than the info data sheets that come out.

(Van Tine): Yes, we'll do that. I feel kind of bad that I've been doing this since 1977 and I've just sprung it on some people today. It's the first time they've heard it, and they live almost next door.

(Art Tautz, MOE, Vancouver): Are we at the limit of our technology of where we're going to go, or do you as a group see that there's a lot more potential out there? How, Jim, do you see it in terms of lakes and coho?

(Van Tine): I've shown that fish can be produced, but I don't really understand a lot of the things that are going on up there. There's massive data gaps, and I would think until we start looking at those kinds of things, that we probably are limited. I think we have to go in there, and I think we only move forward in the fisheries field nowadays through technology.

I don't think that our common sense is really going to get us anywhere. We have to come out of the art of fish culture and go into the science of it, or of fisheries.

I think that we're definitely going to have to understand those systems better, I mean, which lakes produce coho, and which don't. Do the coho stay in the lakes, or don't they? We don't even know.

(Tautz): Kim, maybe you want to respond to that from a research perspective. Certainly, with lake fertilization, there still seems to be a lot of debate about whether it works or whether it doesn't, and we've been at it for a number of years now. How much science do you think is appropriate for something like that?

(Kim Hyatt, FRB, Nanaimo): I think it's a question of the level of resolution we want, and on particular problems, how long we continue to refine our understanding of tightly focused issues, and then how quickly we get along to reallocating our resources.

With respect to lake enrichment, I think that if we took the general attitude that the Alaskan program currently takes, which is that if we can demonstrate that you increase smolt size, that's it, the rest is up to somebody else to demonstrate. A smolt size increase, in fact, is evidence for success, and that's all you have to do, then I'd say the program's successful.

We've already demonstrated that; we've demonstrated that it happens often enough and with large enough magnitude to deliver benefits by inference, which seems to be the source that a lot of habitat research tends to follow. We could get on to broadening the sorts of questions we're asking about how to manipulate lakes and lake habitats for production of not only sockeye, but other species.

On the other hand, the philosophy is that the proof of the pudding has to be changes in total stock returning to particular sites that are being treated. If we've got to demonstrate unequivocally that we're contributing ten percent of the total stock that's returning, or 20, or 30, or 40, we're going to be into decades of assessment where it would take quite a lot of resources, and that's going to limit our potential for expanding into addressing other issues.

I don't see any ready resolution, unless we start to strike some policy guidelines on what's enough evidence to go on.

(Skeesick): I think we've got some really tremendous possibilities in the Willamette River basin (Oregon). There are about five of the reservoirs that have fish passage facilities, or they have at least some capability of getting smolts out. Currently, only one of those reservoirs is being used for production of spring chinook smolts from planted fed fry. Certainly, the other four have an immense potential. By adding additional organic matter to the reservoirs and increasing their basic productivity, we certainly should be able to see a significant increase in spring chinook production.

In our case, it's not nearly as hard to make a determination of what your benefits were, because those fish are going to have to come back to the bases of the dams where they can be captured and counted anyway.

It would seem like a pretty short turnaround from actually doing the work until you begin to see the benefits of it.

I don't know if you folks are aware of it, or not, but there's an immense spring chinook fishery in the general Portland area. The number caught is somewhere in the neighbourhood of 15,000 fish a year. It is a really impressive fishery in the Portland Harbour area, and certainly every 100 additional fish that we can put through that area is going to have a tremendous impact on a very high quality metropolitan area fishery.

(Tautz): You mentioned critics of your program. Is it hard to sell because of the uncertainties of the data, or what are those difficulties?

(Skeesick): No, I think for the most part, just about everybody I've talked to has been really enthusiastic in their support of it. I've got a tremendous number of calls from places I've never heard of before, from Montana, and from central California. There is a tremendous amount of interest in it.

Unfortunately, one of the major critics is also the person that controls my purse string at the moment.

(Hyatt): One thing that I wanted to add by way of a constructive comment, and that is that I think we can get a lot more information retrieval for our dollars spent if there's more integration of the studies we do. The Lake Enrichment Program has terms of reference that deal pretty much with sockeye, but the kinds of assessments that we have to do to get controlled precision and controlled accuracy data are the same sorts of assessments that you have to do to assess the carrying capacity for Jim Van Tine's coho outplants into lakes. Some of these kinds of essentially research overtures, might be a little bit better integrated into systems. You could get multiple utility to the information that's being retrieved.

If we were dealing with a particular watershed, as the Alaskans have, and identified it as an experimental area to generate a lot of information, you could put scarce assessment dollars into that and conduct a whole series of studies. The information yield would be more applicable to a wider range of problems.

(Tautz): One of my frustrations, and I'm not a habitat person, but in selling some of these programs, or trying to make decisions about allocations for funds, it's always sort of soft information. You'd kind of like to make it want to work, but you really haven't got that many cases where there are clear-cut successes. Is that a realistic sort of problem with lakes, or some of the other technology as well, or do you think that we're past that in lake fertilization, and with the reservoirs, and with the coho stocking?

When you talk about species interaction, there's another case in point where we were enhancing kokanee at the same time we were enhancing rainbow. We worked out that the rainbow population in Kootenay Lake eats about a million kokanee.

It's a substantial chunk of fish flesh by the time you go through that, and there's always this risk of saying it works all right for kokanee, or it may work for rainbow, but the next level of interaction is something that's never looked at or evaluated very well.

(Harris): That's definitely a problem, and I don't know that we have hard figures, like on Kootenay Lake, a million kokanee, but it's probably in that magnitude. Skaha Lake, which is the next lake down on the chain from Okanagan, has been sort of a major kokanee experimental area for the Fish and Wildlife Branch. This past year, there were maybe ten fish that people had brought into the Branch office there, kokanee in the six to eight pound category, which are just absolutely monstrous for that lake system. Usually, one or two pounds is a real good sized kokanee out of there. Perhaps, one or two of these large fish might be just sort of a possibility, but there was almost a dozen of these really big kokanee being caught. They're almost the size of a regular sea-run sockeye. These fish were sterile, so we worked back from the age of these fish, and looked at what was going on during the time that they might have been in the gravel as eggs. There was a chemical spill from the local mill there in Penticton, and we actually got a charge under the Fisheries Act, for a spill of biphenyl into the river channel. You want to be careful how much of this information actually gets out to industry, or they may be trying to pump out biphenyls as an enhancement project.

(Van Tine): One of the things that I neglected to mention during my talk about coho colonization is that I think that water flowing downstream with no fish in it is very hard for you habitat people to protect. Therefore, I think if we can get on with some coho colonization, then I think it will really give you a reason to protect some of the habitats that might otherwise be lost.

(Tautz): Good point.

(Skeesick): I was very interested in your comments, Kim (Hyatt), about having lake-resident coho where there are also sockeye. One of the things that I have always felt quite embarrassed about in Oregon is the decline in the run of natural coho into the Ten Mile Lake system, which is about midway on the Oregon coast.

At one time, it had a run in the neighbourhood of 100,000 fish a year, and was made up primarily of the nomadic coho that drop back out of the small tributaries into the two lakes. I think they were about 1,600 acres apiece. The juveniles did very well in the lakes and went to the ocean, and many of them came back. Due to introduction of various species by anglers down there, that population has dropped to about 5,000 fish. As far as I knew, that was really the only naturally occurring lake-rearing coho stock that we had. I'm encouraged to hear that you know of others, and I guess I'm curious as to whether you think that those are actually a genetic variant from the regular stream-rearing coho.

(Hyatt): I'm not sure whether they're a genetic variant or not. The lakes that we're looking at don't really have extensive tributaries, and so most of the spawning is going to have to go on in the very lower reaches of the streams that are right adjacent to the lakes. The lake-shore areas provide pretty good rearing habitat, as evidenced by the numbers and size of what's coming out. We would never see these fish if, two years back, I hadn't decided to check our hydrocoustic estimates of population size on sockeye. To do that, we've put smolt counting fences on two systems. Lo and behold, we count everything that comes out, and some of these little lakes produce surprising quantities of fish.

Muriel Lake, a 160 - 170 hectare lake, produces about 15,000 sockeye smolts, 5,000 to 6,000 coho smolts, and it produced 65,000 peamouth chub that migrated out last spring. So, there's a lot of rearing potential in these systems which we haven't been assessing very quantitatively, and we've just started getting a handle on it.

I think if we looked a little further we'd find that this pattern of lake rearing along the shore is quite common.

In Kennedy main, which is untreated, and Kennedy-Clayoquot, which was treated, we see some benefits for lake treatment, for example, on coho, where the Clayoquot Arm fish are twice as large as main arm fish.

I have the feeling that coho rearing in lakes along the coast is actually quite common, but I don't know what the magnitude is, nor how important this might be for commercial or sport fish stocks.

(Charles Scrivener, FRB, Nanaimo): From our stream work at Carnation, there seems to be two basic periods when we see a restructuring in the coho population. There are large fry losses, initially very early in the year, and downstream, large losses again on first fresheting times in the streams in the fall.

Do you have any idea of when these fish enter the lake; if they enter as fry they should be visible on the lake edge?

(Hyatt): They're certainly entering as fry, and we're seeing, in fact, some fry loss from the lakes at the same time as the smolts are going out. Since the counting weirs are right at the outlets of the lake, the only thing I can conclude is that the coho smolts seen coming out in the spring, are the ones that manage to stay resident all winter. They're leaving predominantly as one year olds, or one pluses, and at a substantial size.

(Scrivener): Do you see the fry along the lake shores in the summer time?

(Hyatt): In Kennedy Lake, which is the only site that I've had any kind of littoral zone sampling program go on, the fry are there. You can pick them up in early summer, and you can follow their growth and recruitment patterns along until about mid-July. Then they disappear; I'm not sure where they go to, but we certainly pick them up in the smolt samples the following spring. So, they are still around someplace, they're just not accessible to our sampling gear.

(Scrivener): In most of these lakes, do they have stream systems feeding them?

(Hyatt): The stream systems are very steep, and so the accessible portion of them would just be the sort of outwash fan at the bottoms.

SESSION III--IMPROVING SMALL STREAM HABITATS

Introduction by:
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Consulting Fisheries Biologist,
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Beaverton, Oregon

Larry Everson was to have been here and talked to you about Bonneville Power Administration's Fish and Wildlife Program, but he couldn't make it. So I want to go through that a little bit. Many of you may have heard about the Fish and Wildlife Program going on in the Northwest. It was spawned by the Northwest Regional Power Planning and Conservation Act, of 1980 - '81, something like that. The dates cease to matter after a while.

The Act had two purposes, one was to promote power planning and conservation in the Northwest, and the most cost-effective thing, of course, is conservation, as we in the Northwest know very well.

A second thrust of the Act was fish and wildlife enhancement. The word is used rather loosely. It actually means either mitigation or compensation, depending on how you want to think about it. The budget last year for fish and wildlife enhancement, so to speak, or research, was about four million dollars.
I think the budget this year was in the order of 10 million, and the projected expenditures over a ten year period were between 100 or 200 million dollars, depending on who you talked to, and when you talked to them.

A little bit about Bonneville Power Administration. It's an off-budget federal agency; that means it does not get its operating revenue from taxes, or from Congress. It creates its own budget through the marketing of electrical power. It doesn't do any generating, it just buys and sells, gets power from the federal dams, as well as from private utilities, and P.U.D.s along the Columbia River, and elsewhere. It redistributes, remarkets the power back to the same people they got it from in some cases, and who direct-service customers, the aluminum industry, and so forth, and of course, to the general public through participating P.U.D.s and utilities.

So, all of this money to be spent on fish and wildlife is really coming from ratepayers, some of it comes from ratepayers already, and the rest will come in the form of presumably increased electrical rates.

There was the thing called the Power Planning Council, which was established by the Act, and the Council was given the job of coming up with a fish and wildlife program, as well as a power planning and conservation program, which we won't go into.

The fish and wildlife program has elements which embrace research of various kinds, mostly relating to up and downstream migration, and screens at various hydro dams, and so forth. The thing called hatchery reprogramming, in a nutshell, is to, or was to, use existing hatchery facilities, mostly downriver in the Columbia system to propogate carefully selected stocks, hopefully wild stocks from carefully selected upriver watersheds and drainages. The progeny would be reared to some as yet undetermined size and level of maturity, released into their natal streams where they could grow up and either migrate on their own down the Columbia through the turbines, or be recaptured again and put on barges and trucks and taken around the dams and rereleased into the Lower Columbia.

That's hatchery reprogramming. Instead of building a whole lot of new hatcheries, the idea was to take existing hatchery facilities and use them to propogate and emphasize certain runs, especially in the upriver areas.

Also, there's a program of predator control in the Columbia system. There's only 60 miles or so of free-flowing Columbia above Bonneville, above tidewater now, and that's at the Handford Reach, which is quite a ways upstream. A lot of predators have grown up in the lakes, or at least that's the theory. So, there are a lot of studies and measures being put forward for predator control. Fish passage is a big issue both in upstream and downstream passage. A lot of emphasis is on juvenile mortality going downstream through turbines, and so forth. There's a thing called the water budget. The whole idea behind the water budget is to provide enough water down the Columbia system that doesn't go through turbines during the peak immigration periods, so the juveniles can go over spillways primarily, and not go the corkscrew journey through turbines. The idea behind this is to promote downstream migration, both the speed of it by creating some currents in these long skinny lakes that we've got, and the safety of immigration. It's figured that the juveniles are better off going over spillways than through turbines.

There's a wildlife section in the plan which is devoted to both mammals and birds. A lot of habitat was destroyed or changed dramaticaly in the construction of the hydropower facilities in the Northwest. There's off-site enhancement, and that is the area of the program which would most closely correspond to the kind of stuff we're talking about here. It's not really enhancement, of course, it's compensation. At any rate, it's got to be done, and I'm very enthusiastic about the program. We're actually doing things and we're spending money on improving habitat in many areas. My feeling is we're going to have a lot of very positive results from that part of the program.

The Council is talking about getting into harvest management, and I'm not sure how far they're going to get with that. There are other entities which have traditionally exercised jurisdiction over that, and will probably continue to do so.

At any rate, they're discussing harvest management issues. The whole program is put together with a series of measures and various sections, each section dealing with one of these major topics, and each measure is funded to an agency or a tribe, or in some cases, the private sector, to be carried out under the contracting authority of Bonneville Power Administration.

The Council sets up the program and Bonneville Power implements it; I guess that's the bottom line.

There is another section in the program which is goals, and in a true bureaucratic fashion the goals haven't been defined yet, probably won't be until the program is completed, but that's not unusual.

There's an entity called the propogation panel, which is a set of experts from various tribes and states, and agencies. The propogation panel is charged, among other things, with setting priorities for implementation of various measures, and for coming up with the goals. That whole thing is in a big state of flux right now.

The propogation panel, which has a rather awesome responsibility, meets one day a month approximately, and to no one's surprise, not a whole lot has got done, but we hope for the best.

There's talk about increasing the work load There are also opportunities for amendments to the program, and amendments nave been turned in already. There will be other opportunities to amend the program, and this is for specific measures; if any entity, an agency, state agency or federal agency, Indian tribe, has an idea that they think ought to be implemented as part of the program, they can submit it under a schedule as an application for amendment. That amendment application is reviewed, and if it qualifies and goes through all the sieves, it is adopted, and recommended for funding by B.P.A.

That's it in a nutshell. I don't want to bore you any more with this program, but it is kind of interesting. I encourage any of you Canadians, to ask any of us about it if you want to know more about how it's set up, about contracting relationships with Bonneville Power, and so forth.

SOME STRATEGY CONSIDERATIONS FOR SMALL STREAM RESTORATION AND ENHANCEMENT WITH SPECIAL EMPHASIS ON HIGH RAINFALL AREA STREAMS SUCH AS CARNATION CREEK

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INTRODUCTION

The need for stream restoration or enhancement programs is recognized by fisheries managers and many people in the public. This view is reflected in the Pearse Commission on Pacific Fisheries Policy, page 54 (Pearse, 1982).

> "In any event, testimony at the Commission's public hearings has revealed strong and widespread support for a shift in emphasis toward protection and rehabilitation of wild stocks, and more balanced enhancement by means of more numerous and geographically dispersed projects aimed at stream rehabilitation and improvement.
>
> In addition to the concerns expressed above, many advocate small-scale projects to enhance natural stocks because they lend themselves to public participation."

Although the desirability of small stream restoration and enhancement may be clear, the complexity of geographical area characteristics, the diverse human impacts on systems, the different specific species needs and the different technical options for different stream systems may not be well recognized.

This paper includes the following:

1. Major emphasis is given to discussion of restoration and enhancement options for streams like Carnation Creek, a small widely fluctuating system in the high rainfall area of the west coast of Vancouver Island.

2. Some aspects of stream improvement on a broader geographical basis are also discussed. Strategies for restoration and enhancement should go beyond the high rainfall areas of the coast and they should consider other elements in addition to biological inventory of watersheds.

3. A description with comments on the major types of climatic and geographic areas in which work may be done in British Columbia is included. The kinds of activities that may be most appropriate to consider in each of these areas. This information is very limited for some areas.

4. A discussion of approaches to stream work, i.e. public involvement, direct work by an agency, or work by industrial users of a watershed.

5. A list of some inventory information that is needed to determine the appropriate restoration techniques and the best institutional approach for doing it.

THE CARNATION CREEK EXPERIENCE

The Carnation Creek Experimental Watershed Project was conceived in early 1971. The primary objectives of the study were to better understand watershed processes affecting fish production and the impacts of timber harvesting on them. The knowledge gained is presently being used during review and revision of the logging guidelines for coastal British Columbia (Hartman et al, 1983). This experimental approach of the project, and its emphasis on watershed processes, can provide information on strategies for improving salmonid habitat in small watersheds.

Carnation Creek is a small stream (10 km^2) which enters Barkley Sound on the west coast of Vancouver Island. The watershed was completely forested in hemlock, red cedar, sitka spruce and amabilis fir. Annual precipitation ranges between 150 and 380 cm which makes stream flows very erratic. The stream contains a large volume of stable woody debris that has accumulated over many years. More detailed descriptions of the project and study area are available elsewhere (Scrivener, 1975; Hartman, 1981, 1983).

Trout and salmon utilize the mainstem, the small side tributaries and swamps, and the estuary. Chum salmon spawn mainly in areas of tidal influence (500 - 4,200 annually) and fry emerge and leave the watershed in March. Coho salmon spawn in the lowest 3,000 m of the creek (160 - 450 annually). Fry emerge in March/April and the population is rapidly reduced by their seaward movement (Hartman et al, 1982). Most of these fry appear to be lost, but a few of them remain in the estuary, become resistant to high salinity water and may smoltify in autumn (Tschaplinski, 1982). The remaining fry rear in the stream for at least one year, although during prelogging years a large proportion of the yearlings remained a second year before undergoing smoltification and moving seaward (Holtby and Hartman, 1982). Steelhead and cutthroat trout occur in low numbers in the main channel and some of the high gradient tributaries. Anadromous forms remain in the stream for two or three years before migrating to the ocean. Trout utilize side channels and tributary swamps at much lower densities than coho salmon.

Chum Salmon

The largest proportion of the fisheries resource in Carnation Creek consists of chum salmon. Their habitat is affected by any upstream perturbations, because they spawn mainly within the estuary. Since 1978, estuary spawning habitat has been degraded by an increase in coarse and medium sands in the gravel. Sand is transported as bedload during freshets which erode stream banks in areas where the stream side is logged (Scrivener and Brownlee, 1982). These sand particles are too large to be dislodged by hydraulic cleaning devices and water velocities are too low to transport them away when flows are low enough to permit instream work. Enhancement strategies of either building side-channel spawning areas or building sand traps above the spawning habitat and physically replacing present gravels are possible. Our gravel quality data also suggests that the frequent freshets could clean the stream bed within a few years, if upstream sources of sand are reduced (Scrivener and Brownlee, 1982). This could be accomplished by stabilizing the banks in areas which were logged.

Coho Salmon

Three general strategies for enhancing coho salmon in small streams are apparent from results of the Carnation Creek watershed study. Use can be made of fry that move seaward during the spring. Exposure of cool, less productive streams to more sunlight and increased nutrients can produce faster development of fry during the spring and summer. Improvements of winter habitat can reduce losses during early winter storms. All three of these strategies involve periods when rapid changes in numbers occur in natural populations (Figure 1).

Egg incubation survival has also been reduced for coho salmon (Scrivener and Brownlee, 1982), so that the number of emerging fry has declined since the watershed was logged (Figure 1). After emergence, fry numbers are rapidly reduced. Seaward movement accounts for most of this early loss and if rearing habitat is provided, these "surplus fry" can be used to enhance or restore the stock (Hartman et al, 1982).

Three techniques are suggested. First, some fry could be returned, upstream. This would be effective only if fry numbers are low in the stream. Since logging, the number of coho fry in Carnation Creek has declined because egg-to-fry survival is lower, because they have emerged early and because they have moved seaward during freshets which are more frequent in the early spring (Scrivener and Andersen, 1984). During May of 1982 and 1983, fry numbers were less than those obtained during September of prelogging years (Figure 1).

Second, "surplus fry" could be placed above barriers in the same or adjacent streams. This expansion of rearing habitat is only useful if smolts can move downstream over the barriers during the following spring. Studies in Quinsam watershed suggest that this is possible (Van Tine, 1984).

Third, more estuary habitat could be created for the "surplus fry" to occupy. Some of the fry that move into the estuary of Carnation Creek in early spring, tolerate salinities of 0 - 19%, and grow more rapidly than their stream-dwelling siblings (Tschaplinski, 1982). Preferred habitat in the estuary contains cover in the form of overhanging banks and vegetation or large debris as in the stream, but the community of food organisms appears richer and more diverse. Coho disappear from most of the estuary after the first freshets in autumn. Some of the larger fry appear to undergo smoltification prior to the autumn freshets (Tschaplinski, 1982).

In cool and oligotrophic streams like Carnation Creek, as many as 60 percent of the smolts are two years old (Figure 1). If some of the canopy over the stream is removed without damaging instream habitat, a longer spring growing season and more rapid growth can occur (Hartman et al, 1984; Scrivener and Andersen, 1984). More coho become large enough to leave the stream after a residence of one year (Figure 1). Also, overwinter survival of juveniles is directly related to their size in autumn (Hartman et al, 1984). This enhance-

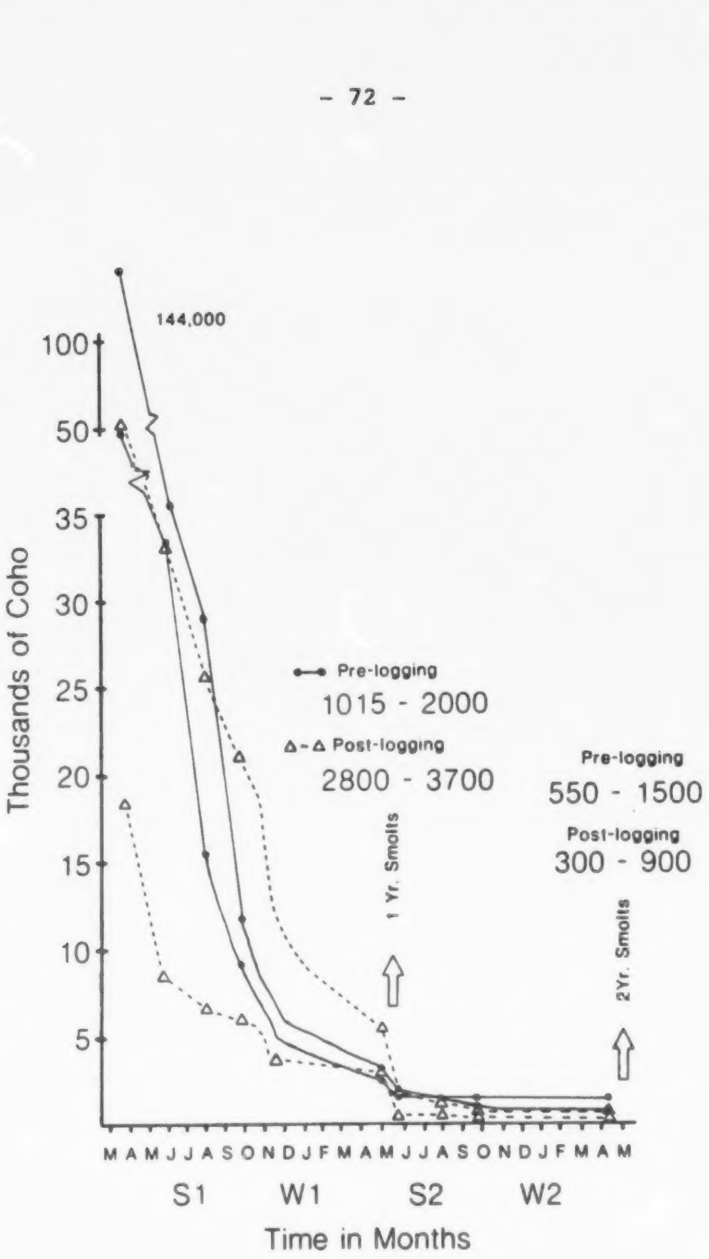

Fig. 1. Coho salmon numbers in Carnation Creek at the time of fry emergence until the seaward migration of smolts. The rangesfor pre-logging (1971-76) and post-logging years (1977-83) are illustrated.

ment strategy could be incorporated in a carefully designed logging plan or silviculture thinning operation. Some large stream-side timber should remain standing as future large organic debris for the stream. This material is critical for fish habitat and stream stability in watersheds like Carnation Creek (Tschaplinski and Hartman, 1983). If some large trees are not left, instream volumes of debris would slowly decline for about 60 years, until wood entering the stream by natural erosion and decomposition processes is large enough to remain stable (Bryant, 1983; Hartman et al, 1983). This material could consist of leaning or poor quality trees.

Improvement of winter habitat is also a useful restoration or enhancement strategy. Although greater adjustments in numbers usually occur before winter, winter influences are likely more important, because they have the final impact on smolt production (Figure 1). If enhancement targetting earlier life history stages does not promote better overwinter survival, it may not contribute to higher smolt production. Four specific approaches to winter habitat improvement are apparent. They include placement of cover such as large debris, side channel or swamp improvement, estuary pond development, and slough construction and transplant to such sloughs.

Placement of large organic debris in streams can provide essential winter cover. It can also improve channel and bank stability about one year after placement (Bryant, 1983). In Carnation Creek pools, numbers of coho juveniles are directly related to the volume of woody debris during winter (Tschaplinski and Hartman, 1983). The stability of any woody debris placed in streams is dependent on its size in relation to channel width, its anchored points, its angle of orientation to flows, and its proportion in and out of the water (Table 1). Its usefulness as fish cover also depends on surface area and on association with other debris (Forward, 1984).

Table 1. Some factors contributing to the stability of large woody debris in streams (from Bryant 1983, Table 2).

Stability	Piece length	Percent on bank	Percent in water	Orientation angle to flow	Anchor points
High	Channel width + 30%	70%	15%	less than 30°	Both ends
Medium	65% to 100% of channel width	30 - 70%	15 - 40%	30° - 60°	1 end on bank
Low	less than 65% of channel width	less than 30%	greater than 40%	greater than 60°	Not anchored or one end in water

Coho juveniles move into tributary side channels and swamps as they fill during the freshets in autumn (Bustard and Narver, 1975). Coho survival in these areas is much higher than among siblings that remain in the main channel (Tschaplinski and Hartman, 1983). Some tributary swamps appear to be underutilized, because fish access is restricted to periods of extreme flow. Increasing water sources and improving fish access can be an inexpensive winter enhancement strategy. Expansion of some swamps which have a large source of water could also enhance utilization.

Construction of estuary ponds as refuge for juveniles that either rear in the estuary or are displaced from the stream by autumn freshets could provide habitat during the last major population adjustment prior to smolt production (Figure 1). The side-channel ponds should be shallow to permit flushing after seawater intrusion, have extensive connections with the stream for easy fish access, and contain extensive cover to promote high densities. They could be constructed during forest harvesting, while heavy equipment is available. Beach logs could be floated in during high tides and be placed in stable positions by the same equipment.

Groundwater-fed sloughs could be constructed in the watershed and stocked with juveniles which are caught in the stream just prior to the autumn freshets. An access to the stream can be opened in the spring to permit emigration. These sloughs should be shallow to permit growth of water plants and the fish food organisms which are associated with their root systems. They should also contain some deeper pools with extensive fish cover.

Steelhead and Cutthroat Trout

Some of the enhancement strategies discussed for coho salmon could also be utilized for trout. In cool and oligotrophic streams like Carnation Creek, trout growth can be enhanced when part of the canopy over the stream is removed (Hartman and Holtby, 1982). During winter, trout also utilize side channels and debris in the stream as refuge during freshets (Bustard and Narver, 1975). Unlike coho salmon, only a few trout enter Carnation Creek. They spawn during early spring and their fry emerge during early summer after the spring freshets. Therefore, early population adjustments and "surplus fry" are not apparent.

GEOGRAPHIC AREAS

On a province-wide basis, we have recognized four major geographic/climatic areas that produce anadromous fish. They have different opportunities for restoration and enhancement.

These areas are:

1. A high rainfall coastal zone--e.g. the west coast of Vancouver Island and the central coast. This tends to overlap the Coastal Western Hemlock Biogeoclimatic Zone (Krajina, 1969).

2. A low rainfall coastal zone--e.g. the east coast of Vancouver Island which tends to overlap the Coastal Douglas Fir Biogeoclimatic Zone (Krajina, 1969).

3. An interior dry area which is represented in part by the Ponderosa Pine--Bunchgrass and the Interior Douglas Fir Biogeoclimatic Zones (Krajina, 1969).

4. An interior cold-winter zone. This is represented predominantly by the Caribou Aspen--Lodgepole Pine--Douglas Fir and the Sub-boreal Spruce Biogeoclimatic Zones (Krajina, 1969).

Although this paper deals mainly with the processes in high rainfall coastal streams, it must be recognized that appropriate restoration and enhancement strategies will be different for these four major areas. The fish species may be different, the critical life history stages can be different, the hydrological regimes are different and the impairments to the habitat may be different. These points may be obvious. However, it is important that they be appreciated so that workers not familiar with fisheries biology, who are involved in restoration or enhancement work, do not attempt to rigidly apply coastal restoration strategies to a cold interior zone. In the coastal zones of Canada and U.S., there are cases of instream improvement activity in which the role of large debris was not understood and it was removed, unselectively, as a stream improvement technique.

GEOGRAPHIC AREAS AND POTENTIAL RESTORATION OR ENHANCEMENT ACTIVITIES

The types of habitat alteration, associated with forest harvest, and planning measures to avoid the negative effects of such alteration, have been dealt with by Toews and Brownlee (1981). A handbook (Lister and Assoc., 1980) goes into considerable detail about stream enhancement and restoration. We will not attempt to duplicate such efforts here. However, we will attempt to present enough summarized material (Table 2) to show the range of options that exist for stream restoration and we will try also to indicate that the measures needed in one area may be very different than those required in another. Some suggestions for enhancement of streams in the dry interior area and the cold interior area came from other sources (G. Taylor, personal communication). Table 2 is not exhaustive. There may be many restoration measures which are appropriate for stream impairments resulting from specific types of land use activity. These have not all been listed. We would stress that different species have different critical life stages. Stream restoration options focussed on a target species may or may not be beneficial to other species present. The options will also depend on the area, habitat constraints, the opportunities and the management plans of both fisheries agencies in the province.

Table 2. Some types of enhancement and restoration activities for salmon, at different life stages, in streams within four major kinds of geographic and climatic areas of British Columbia.

Area \ Life stage	Adult entry and migration	Egg and alevin development	Fry and parr - summer	Fry and parr - winter
High rainfall - coastal	1) Barrier removal - rocks - falls - debris - culvert improvement	1) Slope stabilization - reduce sediment 2) Channel stabilization - reduce sediment - place gabions - place large woody debris - streamside tree planting 3) Gravel cleaning 4) Groundwater channel improvement - See D. Marshall - these proceedings	1) Light addition + temperature increase - streamside thinning 2) Nutrient addition 3) Channel structuring and stabilization to provide diverse habitat structure 4) Slough and off-channel habitat expansion 5) Access opening to new off-channel space 6) Estuarine pond construction 7) Fry transplant to areas above barriers in same system	1) Slope stabilization - reduce gravel + debris 2) Main-stem channel stabilization - provide stable cover and diverse habitat - place gabions + large woody debris 3) Off channel habitat expansion - ponds, side channels, sloughs 4) New off-channel habitat - create ponds in alluvial plain or connect oxbow ponds to main-stem or establish an access to off-channel sloughs
Low rainfall - coastal	1) Barrier removal - rocks - falls - debris - culvert improvement	1) Slope stabilization - reduce sediment 2) Channel stabilization - reduce sediment - place gabions - large woody debris - streamside tree planting 3) Gravel cleaning 4) Groundwater channel improvement	3 - 7 as above 8) Deepen pools - improve wetted area under low flow conditions	2 - 4 as above
Dry - interior	1) Barrier removal - falls - rocks - culvert improvement	1) Channel stabilization - place gabions or large woody debris - streamside revegetation - fence construction - cattle control 2) Gravel cleaning 3) Gravel placement for spawning - lake outlets 4) Water storage and release for fish	1) Water storage and release - for fish 2) Cover placement 3) Increase streamside vegetation for: - fish food - shade 4) Barrier removal - culverts - for movement of young fish 5) Reduce water withdrawal for migration and improve withdrawal facilities	1) Cover placement - rocks or large woody debris - deep areas of stream
Cold - interior	1) Barrier removal - culvert improvement - falls - rocks	1) Channel stabilization - streamside revegetation 2) Gravel cleaning 3) Gravel placement - for spawning - lake outlets	1) Increase streamside vegetation for: - fish food - shade 2) Cover placement 3) Barrier removal - culvert for movement of young fish	1) Cover placement - rocks, gabions or large woody debris along deep areas of stream 2) Off-channel habitat expansion of ponds or sloughs 3) New off-channel habitat creation - connect main-stem to sloughs or oxbow ponds. Freezing problems if no groundwater entry or if ponds are shallow 4) Deepen pools in areas of high ground water input

PARTICIPANTS IN SMALL STREAM ENHANCEMENT RESTORATION

If there is to be a major expansion of small stream projects the planners should consider which geographic areas and which region within geographic areas will receive attention. Groups of small streams which are close to communities and access have the best potential for community involvement. Groups of streams which have not been logged and are in isolated or semi-isolated regions will best have their enhancement or restoration measures planned with, or as part of, the overall forest harvest and post-harvest land use plan. The forest companies may be the group most able to carry out the chosen restoration or enhancement plan. Groups of isolated or semi-isolated streams which have been logged some time before, and left, may not be amenable to restoration through involvement of either forest companies or public groups. These streams will require a different approach and they may be the most expensive type of stream to enhance. Therefore broad plans for restoration and enhancement should be based in part on considerations involving:

1. Anticipated funding.

2. Policy considerations surrounding involvement in planning and execution of programs with forest companies.

3. Considerations of the value of public involvement over and above production benefits.

Plans should also be based upon the best inventory possible.

INVENTORY AND SURVEY

Many of the small streams on the coast of British Columbia have already been logged and affected in a fashion that depends on the method of logging and on the nature of the stream basin. Two of the three types of logging treatment in Carnation Creek have resulted in the destabilization of large debris and its loss or concentration in large piles. The treatments have also affected the channel form.

On the Olympic Peninsula large debris tends to decrease for 40 to 50 years after logging (C.J. Cederholm, personal communication). Therefore many of the logged streams have been changed with regard to channel form and/or debris volume. We believe there is a need for a synoptic study that includes assessment of slope conditions and assessment of the volume, species composition, distribution and stability of wood in two or three groups of similar streams with different logging histories. There would also be a need for assessment of channel structure and fish population characteristics and distribution in such systems. This type of a synoptic study would provide the basis for a review of the opportunities, the problems and the stream benefit/cost relationships of channel restoration with wood or gabion placement. In order to be significant for fisheries production, a program of restoration in such streams would have to be extensive and improvements to the stream channel would have to have stability comparable to that of an unlogged channel. In this sense, habitat restoration implies more than simply placing cover in the stream; it implies an attempt to return the channel to a condition of structural diversity comparable to the pre-logging state. In general, successful natural stream improvement programs must have a strong element of longevity of effect in order to be cost effective.

We recognize that in some cases restoration work may have to be done on spawning or rearing habitat in order to avoid losing a crucial stock of fish. In such cases the decision must not be made on a simple cost and production basis.

There are a number of stream inventory data bases in place now. These tend, however, to be superficial in the level of information recorded. Relative to the present capacity within agencies the data base may be sufficient. However if there is to be a major move toward establishing an intensive small streams restoration program a strong data base is required. The following is a list of elements, with comments on them, that we would recommend in the survey (within a geographic and climatic area) that would provide the basis for selection of the array of streams to be worked on:

1. Stream location
2. Stream access
3. Community proximity
4. Future forest harvest plans
5. Percent logged and logging history, if any.

Comments on 1 to 5

These elements will indicate the best principal participants in the plan: public group, forest company or fisheries agency.

Survey Component

6. Fish species, age composition and distribution

Comments on 6

If a basin has been logged, the species composition, growth rates and fish distribution may all be altered. Restoration project managers may wish to know which species occurred in a stream before logging, because they may wish to re-establish them. It will also be urgent to have good population data to permit an evaluation of the project.

We believe that evaluation must be a major part of a stream restoration and enhancement program if such a program occurs on a major scale. Evaluation will permit workers to improve their choice of techniques.

The high rainfall streams are very variable. It will require substantial "before" and "after" information for evaluation. If a system has restoration work done on it, it will not necessarily "stabilize" immediately. Evaluation is required for a number of years and for a spectrum of project type.

Survey Components

7. Watershed characteristics
    - precipitation
    - run-off pattern
    - soils and geology
    - topography

8. Slope conditions
    - debris torrents
    - slope failures
    - the potential for more torrents and failures

Comments on 7 and 8

If a basin is recently logged, has a flood plain such as Carnation Creek, and has not begun to stabilize, debris used for stream restoration, may float up and strand in big storms. If there is a potential for slope failures or debris torrents, debris and gravel may dislodge or bury enhancement structures. For example, if these structures had been placed in the canyon or in the upper end of the alluvial plain in Carnation Creek, they would have been dislodged or buried in a January 1984 storm.

In the lower part of the alluvial plain, woody debris that was small enough to be placed in the stream by large machinery would have floated up and probably been deposited far away from the stream channel during this storm. Plans for restoration work should consider the type of system and also the rate of change in the system if it is still in a state of rapid reorganization.

Survey Component

9. Channel morphology and composition

Comments on 9

If the stream channel is straight and chute-like and has clay or gravel banks, the structures placed in the stream must initially serve to absorb stream energy and reduce further bank erosion. Gabions or bank armoring logs may do this. If the stream energy can be dissipated in the structures, and channel change slowed, then the more complex features needed for fish habitat can be added. In high rainfall area streams it may not be realistic or useful to attempt to build such complex and stable habitat structures, that over-wintering salmon and trout require, until up-slope conditions have stabilized and until the high energy within the stream channel can be controlled. Both of these conditions will have to be met for channel stabilization along the stream and gravel quality control in downstream zones.

Survey Component

10. Location and volume of large wood for restoration work

Comments on 10

With the survey program, it will be necessary to determine the large woody debris conditions in the channel. If the stream is unlogged and the volume and stability of large wood is considered good for fish production, then the initial planning goal should be to preserve those conditions. If a forest harvest program cannot be carried out without adversely affecting debris volume and stability and if forest harvest is imperative, initial plans for debris replacement should be made. These plans should involve locating and leaving suitable large wood for debris placement and channel restoration. Distance to potential restoration sites and access to them is a key consideration.

If a stream has been logged and large material is needed for restoration work, such material and access to it should be located as part of the survey work. Whole or standing trees will be most useful because of the size requirements for such material and because root masses should be left on trees that are placed in streams. The surveys may reveal that there are some watersheds where there simply are no whole trees or large wood available. In such cases a different restoration strategy will be needed or the stream may have to be left as it is.

Old logging cable may be used to anchor debris. It should be noted in survey work. In current logging operations, companies may be prepared to gather and store old cable on site for future restoration work.

Survey Components

11. Off channel habitat
    - sloughs
    - ponds
    - sites where sloughs and ponds can be created
    - topography for drainage from sloughs and ponds

12. Barriers in the main stem
    - falls
    - rock piles
    - debris

13. Barriers between main stem and off-channel habitat

Comments on 11, 12 and 13

If the conditions in the basin indicate that it is not appropriate to carry out restoration work in the main stem, the efforts may be directed to off-channel opportunities. This work may be applicable to a more limited number of species, i.e. coho salmon and cutthroat trout.

The different kinds of wetting regimes in channels and ponds which are away from the main stem of Carnation Creek, are indicated by specific plant associations (T.G. Brown, personal communication) in the post-logging period. Understanding the vegetation-water regime relationships may be important for planning off-channel restoration. In parts of Carnation Creek, the water table, in summer, was elevated by as much as 70 cm after forest harvest.

Pre-logging surveys of off-channel habitat will provide useful information but they may not reveal where all the wetted areas will be after logging. Because fish in high rainfall streams enter much of the off-channel habitat, primarily in autumn, and leave in spring freshets, it is critical that any new or expanded off-channel space be located so that access for fish is frequently open.

Information about impervious debris piles and falls is used for barrier removal which is known to be one of the most cost-effective enhancement techniques available. Where these barriers cannot be removed, fish may be put above them. In Carnation Creek, there may also be pond and slough habitat above unmanageable barriers. In this case, it may be possible to impound and hold more water above the barrier and transplant fish into the site.

This last section of the paper has dealt very briefly with survey needs and restoration and enhancement responses to survey information. We hope that the specific suggestions are of value. However, we believe that this kind of information shows that there are many different opportunities for restoration or enhancement. These will depend on the species desired, the physical constraints, the funding and participant constraints, and the knowledge of the workers involved. We stress the role of understanding watershed processes because it is only with such knowledge that workers will be able to review survey information, revisit watersheds and prepare the most appropriate plan for a watershed. A rigid approach with limited techniques increases the chances of failure.

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QUESTIONS AND DISCUSSION

(Robert House, USDI, Bureau of Land Management): Can you explain the increased survival from fry to smolt in the post-logging period?

(Charles Scrivener, FRB, Nanaimo): This is smolt output. Essentially, there is a greater survival in some of these years. These are the extremes. I've just put in pre-logging and post-logging extremes. You've got a greater survival in the first few winters. Some of the extremes can be related to the fact that you've got fish that are more successful at surviving the winter.

The second part of it is that almost all of them now are leaving at year one instead of staying in the stream. They're showing a 50 percent relationship. If 2,000 leave as smolts, 1,500 or 2,000 stay in the stream for a second year in the pre-logging situation. So, you had 4,000 yearlings, opposed to this situation where almost all of them left as yearlings. There's not that much difference in the numbers that are left at age one in May, except that most of them are leaving as smolts.

(House): In Oregon, most of them go out as one year smolts.

(Scrivener:) Right. This is what we're pointing at as the potential that you can see from this. We're lumping logging impacts into two types of impacts: the habitat type of impacts, such as the reduced egg-to-fry survival, because of streambed loss, because of increased sands and other fines in the gravel, debris losses, and changes in instream habitat for winter; and other type of impacts, such as the energy and nutrient-related impacts, for example, increased winter temperatures resulting in eggs hatching faster, the fry coming out earlier in the spring.

If they happen to come out in the spring without very much freshets, there's more of them left, they have a longer period to grow. This sort of thing has produced the larger fish that we see. We expect fish to last about 14 years or so in the post-logging phase, before the canopy re-encloses and the nutrients return to pre-logging levels.

The other habitat impacts are likely to be there for 60 years still.

REHABILITATING SPAWNING AND REARING HABITAT IN A DESTABILIZED STREAM BY PLACING GABION WEIRS

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INTRODUCTION

The most destructive type of landslide from a fisheries perspective is the debris torrent, which destabilizes streams, causing the original meandering channels to give way to more chute-like channels. These destabilized channels are devoid of the integral logs which provide stream diversity and stabilized pockets of spawning gravels and rearing areas. Debris torrents and streambank logging practices intensify gravel scour by reducing the frequency of "organic steps" described by Heede (1972), thereby increasing streambed gradients and stormflow velocities. Reductions in stable large organic debris decreased both channel "roughness" and abundance of gravel associated with the debris (Swanson et al, 1976). Additional streambed instability and degradation may result from sediments released from damaged banks or depositional zones of landslides.

Recent developments of instream structures have successfully produced stabilized spawning areas (Hall and Baker, 1982). Gabion weirs (wire cages that are placed into the stream bottom and filled with small rock) were one of the several stream rehabilitation techniques evaluated by the Fish/Forestry Interaction Program (FFIP[1]). Gabions have been found to reduce streambed gradient and to impound gravel beds with a mean particle size typical of salmonid spawning areas (Moreau, 1981). Furthermore, the depth of gravel scour can be reduced by subsequent reductions in stormflow shear stress at the surface of the impounded gravels (Lisle, 1981).

The specific objectives of this study were to: 1) examine the effectiveness of gabions in improving gravel quality as well as the early survival of pink and chum salmon under conditions typical of the Queen Charlotte Islands; 2) identify spawning gravel characteristics related to early survival in pink and chum salmon; 3) examine the cost effectiveness of gabions.

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[1] The Fish/Forestry Interaction Program (FFIP) is a multi-agency sponsored investigation into the extent, causes and amelioration of landslide damage in forests and streams of the Queen Charlotte Islands. The Program is contracted to V.A. Poulin & Associates Ltd. of Vancouver, B.C. One component of FFIP undertaken by the author was to evaluate gabions as a rehabilitation technique for landslide-damaged streams. Data from this study were also used in a Masters thesis in the Department of Forestry at the University of B.C.

STUDY AREA

Sachs Creek on the northeast end of Moresby Island was selected as the study stream for this project. Sachs Creek drains into Skidegate Inlet and is about 11 km long within a 19 km^2 watershed. Its bedrock type is mainly sedimentary. The stream discharge averages about 0.3 m^3/s (12 cfs) during the fall with stormflow discharge up to about 65 m^3/s (2,300 cfs). Summer low flows are about 0.07 m^3/s (2 - 3 cfs).

METHODS

Gabion Description

Gabions (0.91 m high by 0.91 m wide) consisted of galvanized steel twisted mesh (3 mm diameter, 8 cm by 10 cm aperture) manufactured by Maccaferri Gabions. Combinations of gabions 1.82 m, 2.73 m, and 3.64 m long were wired together to span the stream.

Study Site Locations

Three sites on Sachs Creek were selected for gabion installation. Gabions were installed in pairs at each of the three treatment sites and were matched with two control sites to enable statistical evaluation of the results. The study was conducted from spring 1982 to spring 1984. Study sites were selected largely using criteria developed in northern California (Moreau, 1981). Treatment Site I was in an unstable reach at a three percent slope gradient. Treatment Sites II and III were at a one percent slope gradient.

Gabion Construction and Installation

Selection of a gabion configuration followed review of several tested in Washington, Oregon and California (Anderson and Cameron, 1980; Engles, MS 1975; Moreau, 1981). Moreau (1981), in California, found that a paired V-shaped configuration (apex downstream) was the most successful design in trapping bedload suitable for salmonid spawning and withstanding stormflows. This configuration was used at Sachs Creek (Klassen, 1984). The top of the upstream gabion was positioned 50 cm above that of the original streambed. The elevation of the downstream gabion was about 20 cm below the upstream one. Gabion trenches were excavated to provide an 8 cm to 15 cm drop along the top of the gabions from the streambank to the apex, thus ensuring concentrated waterflow for fish passage during critical summer low flows. The gabion ends were buried up to 4 cm in the streambanks, and protected by riprap. To permit site usage by a large run of pink salmon, anticipated in fall of 1982, gabion sites were filled with gravel suitable for spawning to a height level with the top of the gabions.

Instream work was carried out under guidelines and permit of the local Department of Fisheries and Oceans and provincial Fish and Wildlife offices. Crew size varied from one to five during construction, and a 1.25 $yard^3$ bucket excavator was contracted.

Site Analysis

Prior to gabion construction, gravel quality was measured to provide baseline relationships between treatment and control sites. Streambottom contours were also surveyed prior to gabion installation. Intragravel dissolved oxygen was determined from 100 ml samples per site of intragravel water extracted from 25 cm below the gravel surface with a stainless steel syringe and measured with a YSI oxygen meter. Intragravel permeability was measured 25 cm below the gravel surface with a Mark VI standpipe (Terhune, 1958). At Treatment Sites II and III, gravel was sampled with a McNeil gravel sampler and sieved for analysis.

Following gabion installation gravel quality, site stability, spawner utilization, egg survival and juvenile salmonid utilization were analyzed to detect differences between treatment and control sites. Gravel quality parameters were remeasured one year after installation. Gabion sites were resurveyed four to five times after installation. Depth of gravel scour was closely monitored as a measure of gravel stability. The vertical erosion monitors employed consisted of a column of eight perforated plastic golf balls threaded through with 100-pound test monofilament line with a plastic disc at the distal end. The assembly was inserted vertically into the gravel (Klassen, 1984). The number of balls scoured out of the gravel after a stormflow event was used as a measure of the depth of scour at that location.

Two methods of measuring the suitability of treatment sites as salmon spawning habitat were examined: 1) tabulation of salmon spawner activity on all control and treatment sites; and 2) evaluation of habitat suitability based on probability-of-use (Bovee and Cochnauer, 1977) curves developed for Sachs Creek pink salmon. Parameters measured included average water depth, water velocity at spawner "nose height," and surface substrate composition.

To determine differences in egg survival between gabion and control sites, eggs were extracted to a depth of 40 cm with a hydraulic egg pump (McNeil, 1964) at Treatment Site III and its two controls. Two methods of calculating egg survival (McNeil, 1964) were applied to the egg sampling data. First, the ratio of live to dead eggs sampled was used as a relative measure of survival to date-of-sampling. A second method was developed to eliminate the bias in survival introduced from natural egg loss. This method required calculation of potential egg deposition from adult fecundities, egg retention, and spawner mapping data.

Juvenile salmonids were enumerated on the gabion and control sites on Sachs Creek in summer 1983 to indicate the effect of gabion installation on salmonid rearing habitat. Juvenile enumeration involved sampling with both electroshocker (Smith Root, Type VIII) and pole seine (3 m long, 4 mm mesh). Juvenile coho and steelhead were marked by caudal fin-clipping to enable enumeration by the Petersen single census mark-recapture technique. Their fork lengths were measured to detect possible differences in size between the gabion and control sites.

RESULTS AND DISCUSSION

Site Stability

Gravel scour and aggradation was high at all three gabion sites during stormflows in the first winter after construction. These actions resulted in three pool/riffle sequences where there had previously only been one. Bank scour in the downstream lateral corners of the gabion wings, produced by the lateral component of flow perpendicular across the gabions, prompted riprap placement where there previously had been none. Reshaping of gabion sites by stormflows was expected to decrease over time, owing to self-armouring of scoured high-flow channels that developed after gabion installation. Streambed configurations appeared to have achieved an equilibrium in year two at the sites at one percent slope gradient. Gravel scour here was statistically comparable to their control sites. The substantial decrease in local streambed gradients found at the gabion sites probably was responsible for part of the stabilization effect (Lisle, 1981) evident at the lower two treatment sites (II and III). However, the high energy of the site at three percent slope gradient, combined with the inherent instability of the stream reach, caused the loss of much gravel, the scouring of a very large plunge pool, and the inundation of boulders on the site.

Gabion Quality

Gabions in this study were successful in creating high quality salmonid embryo and alevin incubational properties in their entrapped gravels. Results of gravel quality analysis varied between the sites, and hence are discussed separately.

Changes in gravel quality at Treatment Site I could not be determined, owing to the coarse nature of streambed materials prior to gabion installation; coarse substrate precluded sampling of permeability and gravel composition before gabion installation. The decrease in intragravel dissolved oxygen was probably because the oxygen levels were already very high here prior to installation.

Intragravel permeability and dissolved oxygen both increased significantly after gabion installation at Treatment Site II (Klassen, 1984). No change in fine sediments was detected with gabion installation.

Three of the gravel quality parameters measured indicated the gabions at Treatment Site III resulted in increased quality of incubational habitat. The fine sediments found in gravel samples decreased with gabion installation. Intragravel dissolved oxygen increased significantly. Intragravel permeability also increased, but was matched with increases in its controls.

Spawner Utilization

The gabions succeeded in producing gravel beds suitable for salmon spawning, as indicated by both spawner observations and calculated probability-of-use. Treatment Site I was upstream of pink and chum distribution, but had greater coho usage than its control sites. Pink usage at Treatment Site II was greater than one of its controls but less than the other.

The observed utilization of Treatment Site III was lower than its control sites. If the longitudinal distribution of spawners was considered, the utilization of Treatment Site III would also be between that of its controls.

The probability-of-use of the gabion sites at one percent slope gradient were between that of their control sites. Treatment Site I may not have had spawning habitat suitable for pink salmon, owing to its steep slope gradient (three percent) and resultant high energy of stormflows.

Egg Survival

Gabions in this study did not significantly improve early survival of pink and chum salmon in the first year after their installation. In contrast, a study in Washington suggested that gabions there improved chum egg survival during their first year of operation (Gerke, MS 1974). The average pink salmon egg survival to December at Treatment Site III and its two control sites (11 percent, 11 percent and 7.9 percent respectively) lie within the range of other coastal streams. Egg survival was expected to be higher in the future with egg losses caused by changes in site morphology in year one anticipated to be reduced in subsequent years.

Juvenile Utilization

Substantially higher juvenile salmonid densities were found at gabion sites than at control sites (1.6 and 0.9 $/m^2$ respectively). High juvenile densities at the gabion sites in this study were in agreement with increased coho densities at gabion sites placed on other coastal streams (Ward and Slaney, 1981). The ability of gabion sites to accommodate higher juvenile densities was indicated by the length frequencies of the 0+ coho; these were significantly greater than three of the six control sites (p less than .05; paired t-test). Gabions increased rearing habitat diversity by creating two additional pool-riffle sequences per site and by increasing cover available in the form of riprap, cutbanks and nooks and crannies within the gabions.

SUMMARY OF POSITIVE AND NEGATIVE EFFECTS OF GABIONS

The effects of gabion installation on the physical-chemical and biological parameters measured on study sites in Sachs Creek were primarily positive. In relation to salmonid production, the beneficial effects of gabions on gravel scour and streambed slope gradients outweighed the negative three to one. Similarly, gravel quality parameters showing beneficial effects of gabions outweighed those with negative by seven to one. Observed spawning utilizations, adjusted for longitudinal spawner distribution, yielded one positive and one negative indicator.

The effects of gabions on suitability of spawning habitat was variable with one positive indicator, three neutral and two negative. Both of the egg survival indices showed beneficial effects of gabions. The indication of 10 positive to two negative physical-chemical effects of gabions suggest that future egg survival at gabion sites may be expected to be greater than that observed in this study in the first year of operation. Similarly, only beneficial effects of gabions on juvenile salmonid production were found by this study (six positive indicators).

In summing the positive and negative attributes per site, Treatment Site I ranked lowest with five positive to three negative indicators, probably owing to the effects of a steep (three percent) slope gradient. Treatment Sites II (six positive to one negative) and III (eight to zero) indicated there were substantial site improvements with gabion installation at these sites. The overall ratio of 19 positive to four negative suggest that gabions may be an effective way to rehabilitate streams.

Preliminary Benefit/Cost Analysis

The cost effectiveness of gabion installation in Sachs Creek remains preliminary to date. Although the costs are known, the increase in fish production and the longevity of the gabions are not. There was an obvious trend of decreasing installation costs with experience of installation (from $5,200 to $3,800 to $3,000). Gabion longevity is dependent on both the integrity of the structure and the resistance of the wire mesh to abrasion and rust. Similar structures have withstood floods of 100-year return periods in Oregon (Anderson, 1981). Longevity of the gabions in this study may be dependent on the local slope gradient of the stream. The dynamic nature of stream morphology in higher gradient (more than two percent) reaches, especially those rendered unstable from poor streamside logging or debris torrents as at Treatment Site I, reduced the likelihood of adequate structure longevity. However, the ability of structures in the one percent slope gradient reaches to withstand a major flood in August 1983 without shifting suggested that gabions at low slope gradient gabion sites may have a longevity of a couple of decades. Abrasion also was more prevalent at the higher gradient gabion site (Treatment Site I) in this study than at the lower gabions (Treatment Sites II and III). Rusting of the mesh was not evident but may limit the useful life of the structures.

Benefits of gabions, described in previous sections, included anticipated increases in salmonid egg-to-fry survival and increases in summer juvenile salmonid densities and rearing habitat. In addition, many adult salmon were observed "holding" or resting in water ponded upstream of the gabions in autumn 1982 and 1983. Although gabions may make significant contributions to fish production through the described benefits, it is only through anticipated increases in pink salmon egg survival that analysis was made. The actual cost efficiency of gabions would probably be greater than the following analysis suggests if the other benefits of gabions were included.

A benefit/cost analysis was made to determine what production goals were required to offset gabion construction costs with sensitivity expressed over their expected ranges. Analysis was in keeping with the Salmonid Enhancement Program calculations, including harvesting and processing costs, and rate of exploitation (Klassen, 1984). At a 10 percent discount rate with a gabion longevity of 12 seasons, 375 fish additional to the 120 initially spawning on the site are required biennially (major pink runs are on even years only) to offset construction costs. A production of this magnitude (about four times natural survival) may be attainable for gabion sites, owing to improvements of gravel quality with anticipated increases in egg-to-fry survival as discussed. Achievement of cost effectiveness becomes more probable at lower interest rates and greater longevities (e.g. at a five percent discount rate with a gabion longevity of 18 seasons, a doubling of egg survival is required) and when benefits of gabions other than increases in pink salmon egg-to-fry survival are also considered.

CONCLUSIONS

1. Gabion weirs surcharged with gravel created streambed configurations yielding moderate quality spawning habitat for pink and chum salmon in sites at one percent slope gradient reaches. Although another site at three percent slope gradient was utilized by coho spawners, it was not suitable for pink spawners.

2. Stability of gravels entrapped by the gabions at the two one-percent slope gradient sites was demonstrated in year two after considerable site reshaping by stormflows in year one. However, the short duration of this study precluded conclusions on gravel stability at gabion sites during major stormflow events. The gabion site at three percent slope gradient failed to stabilize gravels, owing to the high energy of stormflows there.

3. Quality of the surcharged and natural gravels entrapped by the gabion sites was conducive to high egg-to-fry survival. Intragravel dissolved oxygen and permeability, and gravel composition measurements indicated either improved or good incubational habitat. The apparent "stability" at the gabion sites at one percent slope gradient in year two suggested that the high egg survival demonstrated here during an "unstable" year one would yield substantial increases in the future.

4. Juvenile salmonid rearing habitat was created with the development of two additional pool-riffle sequences per gabion site. The good quality of this habitat was demonstrated by high juvenile densities at the gabion sites compared to the control sites.

5. Preliminary benefit/cost analysis projected required increases in pink salmon production for various gabion longevities (e.g. about a 300 percent increase over a longevity of 12 years). Cost effectiveness may be attainable, especially at lower interest rates and greater gabion longevities, owing to the effects of high quality and stability of gravels entrapped at the gabion sites in increasing egg survival.

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PROVINCIAL STREAM HABITAT IMPROVEMENT

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PREAMBLE

At the outset, it would probably be useful to more precisely define what we mean when we talk about stream habitat improvement. In its broadest sense, fish habitat improvement includes any treatment of a watershed which favourably influences fish habitat and results in increased fish production. There are really two meanings which can be attached to the term "habitat improvement." Improvement can imply restoration or the bringing back of habitat capability to a previously existing level, while enhancement, on the other hand, implies exceeding some base level or previously known level of production by alleviating a production constraint. An example of restoration would include the installation of boulder groupings to replace trout rearing habitat lost during flood control activities (e.g. channelization). Enhancement would be illustrated by construction of a fishway at an impassible barrier to provide upstream fish access and use of new habitat, thereby considerably enhancing production over historic levels.

For purposes of this discussion the term improvement will be used to encompass both the restoration and enhancement meanings.

To briefly put the Province's stream habitat improvement activities into perspective, by far the most important incentive for development of Provincial expertise in this field was the advent of the Salmonid Enhancement Program (SEP) in the mid-1970s. While SEP's production targets have largely been achieved by lake fertilization and major fish culture facilities, a significant amount of funding has been directed to more natural restoration and enhancement techniques for stream-rearing salmonid populations. Both the public (represented by the Salmonid Enhancement Board), and several outspoken Federal and Provincial biologists, have continued to promote the need for a greater balance between wild and artificial production in SEP's operations. A result of this lobbying has been the widespread application of traditional and new habitat improvement technologies to streams supporting anadromous salmonids throughout the province. The provincial government has used these same techniques for improving sportfish production in non-anadromous, inland waters.

All of the various stream improvement methods have been used with success in British Columbia. In appropriate locations they have demonstrated positive benefit/cost ratios. Many of the techniques have been used in public involvement projects involving small stream improvement. The popular Stream Enhancement Guide was jointly produced by federal and provincial fisheries agencies to better inform the participants in such projects of the range of techniques available, and their limitations in use. The Province has pursued with the public the hazards of transferring live fish between aquatic systems.

The assessment of habitat improvement opportunities must initially include the determination of the status of fish populations, and what features of the stream environment may be limiting fish survival and production. This will normally require an intensive biophysical inventory which can provide appropriate alternatives for improvement of fisheries through habitat manipulation and creation. Data are collected from streams under natural, degraded, restored and enhanced conditions for the purpose of comparing habitat production capabilities.

In British Columbia, anglers presently catch about eight million freshwater fish annually, of which 75 percent result from natural production. The management premise from which the Province operates is that most anadromous and inland fish production is, and will continue to be, heavily dependent on wild fish produced by natural means. In view of this, the following eight techniques have demonstrated that in specific situations they can produce additional wild fish for the angler.

HABITAT IMPROVEMENT TECHNIQUES

Improve Spawning Access

One of the most widely used, well documented and potentially beneficial fisheries improvement measures is the removal of barriers to provide upstream access for spawning adults and, in some cases, juveniles. Techniques to accomplish this goal include construction of fishways, blasting and physical removal of obstructions, stream clearance directed at opening up debris jams or breaching beaver dams, and baffling or back-flooding of problem culverts.

The Department of Fisheries and Oceans and the International Pacific Salmon Fisheries Commission have been the lead agencies in the design and installation of major fishways in the province. Where such facilities have been installed to accommodate salmon species, they undoubtedly have also provided passage for adult steelhead. It should be recognized, however, that these same facilities may not be adequate to successfully pass smaller sportfish species such as sea-run cutthroat trout. In systems where cutthroat are present, it would be useful for the Province to have an input to the design of proposed fish passage devices.

The Branch's experience with providing upstream steelhead passage has included blasting of bedrock falls in the Salmon River (northern Vancouver Island), and at Harold Price Creek (a Suskwa River tributary). The Branch is also involved in the design of adult steelhead and smolt passage facilities for the John Hart diversion on the Salmon River. A proposal will eventually be presented to B.C. Hydro for funding consideration.

Usually very little risk is involved in providing spawner access to barren habitat. Low to high risk may be associated with under-utilized habitat where other species are present. Colonization of newly accessible habitat can be accelerated by transplanting adults, eggs or fry into selected areas of the watershed (e.g. Salmon River, Harold Price Creek fry stocking). Where stream sections above obstructions are inhabited by populations of resident cutthroat trout and/or Dolly Varden char, some evaluation of growth and survival of introduced species should be undertaken at index sites or, at best, in the stream to be affected.

It is likely that there continues to be a substantial potential for improving access for anadromous salmonids in British Columbia. As an example, major production increases for coho, sea-run cutthroat and steelhead could probably be realized through an extensive program of problem culvert modification and replacement.

Natural Spawning Improvement

The quality, abundance and distribution of spawning gravel often establishes the limit of salmonid recruitment in streams. Where existing gravel is judged to be limiting, there are a number of habitat improvement options available to fisheries managers. One such option involves the technique known as gravel scarification. Gravel beds are mechanically raked or groomed so that fine sediment and organic particles are brought to the surface and flushed away by the stream's current. A large spawning channel for kokanee is annually scarified by a bulldozer equipped with rake-like blades to improve subsequent egg-to-fry survival.

In Washington state, prototype gravel cleaning equipment has been developed which involves the use of high velocity hydraulic jets with suctions and separation systems to remove silt and sediment from spawning gravel, and spraying the material on stream banks above the high water mark. The average period of effectiveness following gravel cleaning is about three years, and benefit/cost ratios have ranged from about 12 to 27:1 (Mih, 1979).

Provincial fisheries staff have experimented with a similar approach using a nine horsepower fire pump and high pressure nozzle for cleaning both resident trout and steelhead spawning gravel (e.g. Ruby Lake spawning channel; Camera channel on Atnarko River).

A second option for improving natural spawning conditions is to introduce new gravel to streams judged to be deficient. Gravel of the appropriate size is placed in "cribs" constructed of either boulders or anchored logs to create a spawning platform. Gabions (rock-filled wire baskets) can also be used to provide the necessary structural support.

Gravel placement in lake outlets can be undertaken to improve steelhead and chinook spawning success. Two examples where this has been done include Chilliwack and McDonell (Zymoetz system) Lakes. The Fish and Wildlife Branch has also constructed gravel platforms in side channels and small tributaries to large stream systems which are recognized as important steelhead spawning areas (e.g. Camera channel, Chilliwack River tributaries, Karen Creek). To remain effective and durable, platforms should be placed at stream sites where gravel tends to collect naturally, and in small systems they should be placed across the entire wetted width to minimize the risk of relocation and gravel loss.

In Washington, the benefit/cost of spawning gravel replacement is given as 3:1 by Mih and Bailey (1979).

Spawning Channel Development

A spawning channel is an engineered facility which attempts to duplicate all of the best characteristics of natural salmonid reproductive habitat by providing a reliable flow of cool, clean water over gravel of prescribed shape, size and composition at a preferred slope. Provision of holding pools and overhead cover (in the form of planted bank vegetation) is also normally required. Spawning channels are most often constructed to improve recruitment from species requiring minimal or no periods of stream rearing such as chum, pink and sockeye salmon.

To date the Fish and Wildlife Branch has not constructed any conventional spawning channels to accommodate steelhead and sea-run cutthroat trout. A somewhat modified steelhead spawning-rearing channel was designed for a small tributary to the Coquihalla River, as partial mitigation for construction of the new Coquihalla Highway. The implementation of this project remains on hold however, pending a final decision on the alternative for off-site compensation.

Improve Rearing Habitat

When an extended period of stream rearing is required by anadromous salmonids before reaching smolt stage, the potential number of outmigrants is largely determined by the amount and quality of available rearing space. Implicit in the term "quality" is the presence of diverse and stable cover within the stream channel. Natural cover may consist of large boulders and cobbles, bank undercuts, overhanging vegetation, deeper pools and debris such as logs and roots. The presence and distribution of these elements essentially define the individual territories of young fish.

In many small streams in urban areas, natural cover has been deliberately removed to increase hydraulic efficiency and reduce flood threats. In some larger systems, cover diversity can be restricted to stream edges with much of the channel cross section unoccupied by fish as a result.

The manipulation of stream channels to provide cover and create rearing habitat for sport fish has been practiced for many years, particularly in eastern North America, but also in western states such as Wyoming, Montana, California and, more recently, Oregon. In this province, SEP-funded research has focussed on investigating the utility, durability and cost-effectiveness of different structures placed in streams to increase summer and winter rearing habitat for juvenile steelhead, coho and cutthroat (e.g. Keogh River, Colquitz Creek, Lower Mainland small streams).

Various techniques have been used including boulder groupings, anchored logs and roots, and gabion configurations. Generally the boulder installations have proven most successful, both in terms of durability, and in their use by juvenile salmonids. However, an increase in stream carrying capacity at treated sites can only be realized when fry recruitment and subsequent summer flows are adequate.

In most instances, larger rock (i.e. 45 to 60 cm) should be used, with triangular clusters of three to five boulders installed in the downstream ends of established riffles. In very small streams (i.e. less than five metres wetted width), however, experience suggests that a "blanket" approach should be used, with high density rock placements occurring in all habitats and over the entire wetted channel cross section. Again, larger rock is less prone to displacement and burying in fine substrate.

Benefit/cost analysis of the Keogh River habitat complexing project indicated a benefit/cost ratio of 1.4:1 after 10 years and 2.2:1 after 20 years (Ward and Slaney, 1979). For the Colquitz project, benefit/cost ratios are 4.6:1 after 10 years and 7.2:1 after 20 years, assuming optimum summer discharge (Ptolemy, in preparation).

Flow Stabilization Through Storage and Diversion

Both spawning success and the maintenance of suitable rearing conditions are highly dependent on the range of stream discharge. For example, low flows during the spawning period can expose adult fish to greater predation or contribute to high egg mortality in exposed redds. Where extended stream rearing is required prior to attaining smolt size, low summer flows can be decisive in determining the eventual number of outmigrants (i.e. available space regulates the number of fish supported in a stream).

Headwater storage may be a practical solution to a low-flow problem where sufficiently high benefits can be demonstrated to justify development costs. Natural runoff captured in a storage facility can be released at rates needed to maintain desirable spawning, incubation and rearing conditions in downstream areas. As an example, the Fish and Wildlife Branch has recently undertaken a relatively small lake storage project on the Keogh River on northern Vancouver Island. Water is currently released from behind a low-head dam to provide sufficient flows to a section of the upper river where a stream enrichment project is in progress (E. Parkinson, personal communication).

Similarly, the provincial government is currently cooperating with the federal government in developing a new dam and storage proposal for Nicola Lake, where significant downstream fish production and irrigation requirements must be simultaneously met.

Elsewhere in the province's interior, negotiations have been conducted with irrigation users to secure a more favourable schedule of storage release for both fish and irrigation needs during the summer low-flow period. Screening of intakes, spray versus flood irrigation, and diversion screening are important adjuncts to adequate water use plans.

Where headwater storage is not practical, diversion in whole or in part of one stream into a neighbouring system with inadequate flows might be considered. A considerable amount of planning related to acquisition of appropriate approvals and licences is associated with this option. Of interest is a recent diversion project undertaken by the Fish and Wildlife Branch in the Smithers area. In this case a volatile, glacial tributary to the upper Zymoetz River has been diverted away from an important steelhead spawning area at the outlet of McDonell Lake. The main objective of this project was habitat preservation, with subsequent enhancement in the form of spawning gravel placement downstream of the lake to the junction of the diverted influent stream.

Stream Enrichment

Food abundance is generally considered to be one of the main limiting factors to production of anadromous stream-rearing salmonids, particularly in coastal streams. The Fish and Wildlife Branch is presently conducting SEP-sponsored research on the effectiveness of stream enrichment in nutrient-poor coastal streams (e.g. Keogh River). Enrichment of coastal streams with inorganic fertilizers during the high growth period of spring to fall may be potentially useful in systems with suitable flow regimes. To date, Provincial research has focussed on food chain responses to stream application of inorganic and organic fertilizers. Initial results indicate a greater potential for the use of inorganic fertilizers (e.g. 0-45-0 and 26-0-0 Osmocote R pellet-coating fertilizer). In Keogh River experiments, a significant increase in net periphyton accumulation was observed within one month of fertilizer treatment. In addition, within six weeks of treatment there was a significant increase in invertebrate standing crop. Within two-and-a-half months, this increase in secondary production translated into a doubling of weight-at-age for underyearling steelhead, coho and Dolly Varden, and a 50 percent increase in weight for steelhead parr (C. Perrin, personal communication).

In 1984, a whole-river treatment will be undertaken on the Keogh River with particular emphasis on determining any change in fish density, overwinter mortality and smolt yield. These parameters are essential for evaluating a real fish response to fertilizer applications.

Coarse (Non-sport, Undesirable) Fish Control

Many of the province's lakes and streams that once supported sport fish now contain abundant coarse fish populations which compete with desirable species for habitat and food, or may prey directly on salmonid eggs and juveniles. While the use of piscicides for rehabilitation of stream fisheries has not been endorsed or practiced in British Columbia, it has been widely used in a number of American states. Unfortunately, the record of success in many instances has been temporary, with frequently rapid reestablishment of undesirable species following chemical treatment. Major problems related to achieving a "complete kill" of target species include: difficulties in obtaining uniform dispersal of the toxicant throughout the stream; insufficient concentration of the toxicant and duration of target species exposure over long distances; unavailability of toxicants that are specifically formulated for stream use.

While these factors would likely preclude the widespread practice of stream rehabilitations in British Columbia, the development of new (selective) toxicants and more efficient application techniques may eventually produce a cost-effective means of controlling stream-dwelling coarse fish populations (e.g. squawfish).

Erosion Control and Revegetation

Riparian vegetation is considered important in providing cover, acceptable temperatures and food for stream salmonids. In addition, it may intercept downslope movements of sediment and small debris into stream channels and, therefore, assumes a primary role in stabilizing stream banks. Improvement of stream habitat should include the protection and restoration of natural deciduous vegetation along denuded reaches of watercourses. Appropriate bank revetment measures and reestablishment of vegetative cover might be considered as appropriate mitigation where logging of commercially valuable timber has been approved to the stream's edge.

Where habitat perturbations result from indiscriminate stock watering practices, fencing of riparian areas should be given serious consideration (e.g. upper Loon Lake where three km of stream were recently fenced at a cost of $20,000).

Where stream bank instability threatens major resource losses, or jeopardizes significant enhancement potential, stream diversion (e.g. away from large clay banks) might be considered a justifiable though costly alternative.

Where upslope land use practices generate sediment loading in streams, corrective measures including revetment, proper culvert installations, fencing and hydro-seeding should be treated as legitimate costs of development.

THE ROLE OF FISH CULTURE IN STREAM IMPROVEMENT PROJECTS

Perhaps the most popular and widely recognized approach to fisheries improvement is through the development of fish culture or hatchery programs. In its most simplistic form, a hatchery consists of a controlled, reliable source of high quality water (usually ground or spring origin), and buildings to house the water supply system and fish culture equipment (e.g. incubation trays, rearing troughs, ponds, feeders). Established hatcheries usually also feature equipment for control and treatment of waste products within their water systems.

The Province's fish culture policy continues to dictate that annual hatchery production rely almost exclusively on eggs collected from wild brood stock, rather than from "domestic" strains cultured within the hatchery system. This policy applies to both anadromous and inland species. With respect to SEP, the major thrust of the Province to date has been the stocking of barren or underutilized stream habitat with steelhead and sea-run cutthroat fry. Smolt liberations have also been an important part of this program. As has been alluded to earlier, fry stocking is often viewed as complementary to instream habitat improvement activities. For example, to promote rapid colonization of newly accessible habitat as a result of barrier removal, fry can be transplanted into upper reaches of a watershed. Similarly, in sections of small streams which have received intensive boulder placements, it may be necessary to saturate the treated areas with fry in order to maximize expected benefits (i.e. increased smolt yield and eventual adult returns) early in the life of the project.

STATUS OF APPLICATION

Recent analyses of present and anticipated applications of the habitat improvement techniques outlined in this reporting is presented in Table 1 and generally summarized as follows:

--Obstruction removal is the most favoured measure (50 to 70 percent) and perceived effectiveness (success) is 75 percent or greater. Increase and creation of spawning sites was closely allied to this technique.

--Near stream improvement (canopy manipulation, fencing, bank stabilization) has a somewhat surprising amount of support (comparable to obstruction removal).

--Discharge and gravel manipulation got less than an enthusiastic endorsement in perceived effectiveness (50 percent).

--Fertilization ratings were more a reflection of the untested nature of the technique rather than an indictment of its past effectiveness.

--Instream complexing although recently researched, has been applied in a limited manner (less than 25 percent). It will be applied in future, but effectiveness is judged to be only 50 percent.

--Spawning channel development and undesirable fish control were considered to be last resorts.

Table 1. Major aspects of instituting and maintaining habitat improvement techniques for the production of steelhead, coho, chinook and cutthroat.

Restoration or Enhancment Technique	Problem	Opportunity Presented	Method	Approach		Precautions	How Locations Chosen
				Trained	Supervised		
Spawner Access	Natural barrier	Man-made	Local	yes	yes	Passage of competing species	B/C of upstream area
Natural Spawning Sites	Degradation	Recruit new habitat	Local Abroad	yes	yes	Maintenance	Usefulness for rearing
Spawning Channel Development	Lack of recruitment	Migitation/ compensation	Local	yes	yes	Water quality Predation Icing	Often relative to poor or reduced natural production capability
Rearing Habitat	Limited or Degradation	Activity nearby provides materials (e.g. highway const.)	Local Abroad	yes	yes	More is not necessarily better	To nearby recruitment
Flow Manipulation	Extraction	Control structures	Local Abroad	yes	yes	Competing water users	Dams, low flow problem streams
Stream Enrichment	Low nutrient profile	Capitalize on available habitat or external nutrient source	Local Abroad	yes	yes	Continuity	Basis of habitat available and fish recruitment

Table 1. (continued)

Restoration or Enhancment Technique	Problem	Opportunity Presented	Method	Approach		Precautions	How Locations Chosen
				Trained	Supervised		
Undesirable Fish Control	Predation/ competition	Temporary or permanent reduction	Abroad Local	yes	yes	Maintenance	Standing stock assessment results
Erosion Control and Revegetation	Industrial	Riparian management	Abroad Local	yes	yes	Maintenance and management	as above

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Restoration or Enhancement Technique	Where is Application	Measured How?	Technique Effective	Independent and/or Social/ Economic Benefits	Benefit/Cost	Application to Extend Benefits	Species Life/Stage of Application
Spawner Access	Coastal streams Culverts	New habitat utilized	yes	yes	1:1 to 10:1	yes	Steelhead, coho, chinook cutthroat adults
Natural Spawning Sites	Small streams Lake outlets	Juv. adult standing stock inc.	yes	yes	7:1	yes	as above

Table 1. (continued)

Restoration or Enhancement Technique	Where is Application	Measured How?	Technique Effective	Independent and/or Social/ Economic Benefits	Benefit/Cost	Application to Extend Benefits	Species Life/Stage of Application
Spawning Channel Development	Industrial sites Locations with associated rearing habitat (not so for pinks/chums)	Outmigrants Marked returns	yes	yes	25:1	yes	as above and for juvs. in incubation channels
Rearing Habitat	Small streams Lake outlets Channelized streams	Juv.adult standing stock increases	yes	yes	1.3 11.1	yes	as above
Flow Manipulation	Small to moderate-sized streams	as above	yes	yes	?	yes	as above
Stream Enrichment	Coastal streams	as above for juv.	yes (?)	yes	?	yes	Steelhead, chinook, cutthroat adults
Undesirable Fish Control	Interior streams	as above	yes (?)	yes	?	yes	as above for juveniles
Erosion Control and Revegetation	Small streams in agricultural and urban areas	as above for juv.	yes	yes	?	yes	as above for juveniles and adults

Table 1. (continued)

Restoration or Enhancement Technique	Comments on Usefulness of Technique
Spawner Access	Blasting--high Temporary fishways--moderate Permanent fishways--low
Natural Spawning Sites	Only when in conjunction with useful rearing habitat, where applicable
Spawning Channel Development	Only when "surplus" stocks do not impinge on harvesting of wild stock management plan
Rearing Habitat	Only if all the necessary life-history rearing capabilities are present
Flow Manipulation	as above
Stream Enrichment	as above
Undesirable Fish Control	Interactive biology must be well understood before application.
Erosion Control and Revegetation	No use in instituting if upstream effects negate effort

SUMMARY

Habitat restoration or enhancement is judged by itself not to be everywhere of the same utility in meeting management goals. It certainly is in jeopardy without the integration of habitat protection and research findings.

In combination with good stock recruitment (e.g. initial supplementation by artificial methods), habitat improvement can be very meaningful and necessary in maintaining first the estimated 75 percent of production by natural systems, and providing mitigation and compensation for natural and man-made perturbations.

As in non-anadromous programs, it may well be rationalized that a low benefit/cost ratio can be accepted because of the critical part a project plays in securing desired wild stock production (e.g. reduction of residualism effects apparent in some steelhead hatchery stocks). It is obvious from review of the literature on project "worth" that careful attention has to be taken when commenting on the validity of benefit/cost analyses or making direct comparison of benefit/cost ratios when the criteria used (assumptions made) are not understood or agreed upon, particularly when one improvement technique "worth" is being judged against another or another management tactic. Equally, particular note has to be taken of any project which has high or higher benefit/cost ratios than other tactics, but net contributions are relatively low to targets.

The application of habitat improvement technologies are not a panacea in the absence of other important management tactics. It is most evident, for example, that in isolation, regulation (enforcement) or fish culture or habitat improvement are not the only or ultimate answers.

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DEVELOPMENT AND ASSESSMENT OF GROUNDWATER-FED SIDE CHANNELS

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PROGRAM TO DATE

Since 1978, the Small Projects Unit (SPU) of the Salmonid Enhancement Program has undertaken a program to develop new spawning areas and upgrade existing spawning areas in groundwater-fed side channels. A total of approximately 42,000 m^2 of new and improved spawning habitat has been created at 11 project sites: seven in the lower Fraser Valley, three on the Squamish River system and one on Vancouver Island. A conservative estimate of the potential annual adult production from these projects is 85,000 chum and an additional, but as yet unknown, number of coho. A list of projects is given in Table 1.

Table 1. Groundwater-fed side channel projects

Project	River system	Year constructed	Estimated spawning area (m^2) Pre-develop.	Post develop.
Hopedale Slough	Chilliwack/ Vedder R.	1978	-	1,120
Barrett Creek	Chilliwack/ Vedder R.	1978	-	3,340
Peach Creek	Chilliwack/ Vedder R.	1982	1,320	2,600
Worth Creek	Norrish Creek	1979	-	850
Railroad Creek	Norrish Creek	1979	-	770
Billy Harris Slough	Harrison River	1979	-	7,490
Little Mountain Slough	Harrison River	1981	-	5,800
Lower Paradise Channel	Squamish River	1979	-	1,940
Upper Paradise Channel	Squamish River	1982	1,350	2,625
Judd Slough	Squamish River	1979	Undetermined	12,100
Westholme Channel	Chemainus River	1978	-	2,930

SITE SELECTION

Opportunities for carrying out side channel development projects are present on many medium-to-large-sized rivers provided that river bench land where suitable site conditions prevail are comprised of porous gravel-type soils and there is an adequate supply of groundwater near the ground surface. Other basic site requirements are sufficient gradient in order to provide the necessary flow characteristics for the channel, reasonable protection from flooding, and some abundance of chum and coho that spawn in the vicinity of the proposed development site to ensure that the channel is well utilized from the start. Usually, old fluvial channels that have cut through bench land are selected for development sites rather than the adjacent bench land itself, perched at a higher elevation. This is a cost-saving factor aimed at reducing the quantity of material that must be excavated.

CHANNEL DESIGN

The work involved in developing a channel typically includes grading down the existing channel in order to intercept a larger portion of the subsurface groundwater flow, and lengthening and widening the channel to increase spawning area. This is followed by scarification of the native gravel or, alternatively, the addition of screened and washed spawning gravel. Large cobbles are sometimes recovered from the excavated material and used to armour the channel banks to prevent undermining by spawning fish. Quarry rock or riprap may be used in place of cobbles if a suitable rock source can be found nearby. At a number of sites, low weirs, usually of timber construction, are installed at intervals along the length of the channel. The weirs serve to control the channel gradient and create the required minimum spawning depth of 10 to 20 inches. Finally, at projects where flood protection measures are needed, a spur dyke or dam is installed at the head of the channel. Flood protection needs vary considerably between projects. Usually, sites are selected for development that requires a minimum of flood protection work.

CHANNEL ASSESSMENT

Assessment of groundwater-fed side channel development projects from adult chum spawning through fry emergence is being carried out annually at Worth Creek and Upper Paradise channels. Results of the 1982-brood spawning, which are considered to represent near optimum spawning densities for chum salmon in these channels are summarized in Table 2.

Table 2. Results of 1982-brood chum spawning in Worth Creek and Upper Paradise channels

Channel (Area)	No. Adults (No. Females)	Females per m^2	Potential egg dep.	Fry output	Fry per m^2	Survival rate
Worth Creek (850 m^2)	1616 (615)	0.7	1.8M	0.39M	458	21.6%
Upper Paradise (2625 m^2)	5099 (1965)	0.7	6.7M	2.04M	778	30.3%

CAPITAL COSTS

Capital costs for developing Worth Creek and Upper Paradise channels were approximately \$8,000 (\$9.40 per m^2) and \$22,000 (\$8.40 per m^2) respectively. Screened and washed spawning gravel, rock armouring of the banks and timber weirs were provided at both sites.

BENEFIT/COST ANALYSIS

A benefit/cost analysis of groundwater-fed side channel development projects was recently carried out as part of an overall assessment of the Small Projects Unit program by a team of consultants with expertise in biology, engineering and economics (Anonymous, 1983). The analysis covered all eleven channels completed to date. (See Table 1 for list of channels.) The study team used the existing SEP Production Model which is the conventional tool used by SEP planners to evaluate potential SEP projects. Estimates of salmon production were based on an earlier study of production in groundwater-fed side channels (Lister et al, 1980) and other data and reports in SPU files. Estimates of costs were based on computerized records of SPU expenditures.

The approach used to quantify benefits and costs in the analysis included:

- fish production levels resulting from the various channels were compared with those which would have occurred in the absence of the projects (i.e. only incremental production was considered)
- costs were expanded to include the initial reconnaissance and feasibility studies, capital and administration costs (including wages) associated with developing the projects, and finally, maintenance, assessment and administration costs associated with future operations
- for each channel, a life expectancy was determined based on estimated frequency of occurrence of damaging floods.

The main findings of the study team with regard to the groundwater-fed side channel development program included:

- economic analyses of spawning area developments indicate a favourable benefit/cost ratio of 1.7:1 overall, with individual projects ranging from 0.3:1 to 2.4:1
- considering the (small) scale of spawning area developments and their comparability to natural areas in terms of spawner productivity, it is concluded that these projects will not add to stock manageability problems, i.e. adversely impact naturally-producing stocks. In this respect they must be considered superior to hatcheries as an enhancement technique for chum salmon
- the groundwater-fed spawning areas for chum salmon are a widely applicable technique which will find use not only for enhancement but also for mitigation of impacts from industrial development. The technique appears to be one of the few stream improvement approaches which can provide reasonable long-term benefits at a favourable benefit/cost ratio.

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STREAM MORPHOLOGY AND ENRICHMENT

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I'd like to comment, quite briefly, on two related topics. The first is optimization, or "getting everything right." We all know that many factors limit production of salmonids in streams. Perhaps the most obvious ones are the extremes of flow; freshets that wash fish out and droughts that leave them stranded in pools. Predators play a part, cover, nutrients and so on.

Suppose we had the opportunity to put into a stream any features we wanted. Which would we choose, and what would be the outcome? What increases in production of salmon and trout do you think would ensue?

A couple of years ago, we had an opportunity to do something like this. We attempted to make a stream in which everything was set in favor of the fish, and to please our Provincial colleagues, we chose steelhead.

The simplest way to get flow control in a system is to go to a river with ample water and take a constant amount out of it. A side channel offers this possibility; so we went to the Big Qualicum River and put in a side channel 400 m long and supplied it with 15 cfs of water from the river.

We also made a series of riffles and pools. We had to choose, somewhat arbitrarily, a ratio, and the ratio was two lengths of riffles to three of pools, and this we repeated 25 times.

We chose a medium-sized gravel. It is interesting in making these choices how often they are made on the basis of good knowledge, and how often they are made on the basis of judgement. In some cases the literature is helpful, in other cases, it is surprisingly deficient.

We chose a medium-sized gravel, one inch to about 2 inches, and we provided fish with floating cover. What fish like to do is stay in the dark and look out at what is passing in front of them. We also protected them from the larger predators, in this case herons and mergansers, with a net canopy.

The objective was to see what fish production would be possible in this system. Now, something else was required, and that of course was the master factor in stream ecology, which is the freshet. So we provided, very artificially, our own, which was a fire hose. Once a year, we would wash down the gravel and get rid of the sand. The content of sand is crucial in deciding intergravel space, and therefore the quantity of benthic insects which will be produced to sustain the fish.

We stocked the channel with 10,000 steelhead, kindly provided by the hatchery. We had to wait until they were big enough to tag so we would know what we were dealing with. They were 5-g steelhead.

We put them in the channel and submitted them to a flow of 15 cfs, and the result was a failure. The fish were unable to hold position on a natural diet in these velocities. They became emaciated and they contracted a disease called Cryptobia which is a protozoan disease that invades the fish and causes blindness, amongst other things. So this was rather a severe lesson.

The fish, by the way, occupied the pools for the most part.

The following year, we repeated the experiment. This time, we had the channel at 5 cfs. We again introduced 10,000 steelhead, in spring, we produced a total of 1,200 smolts, rather lean looking characters, of 15 grams mean weight.

This quantity of fish, in terms of unit area, is 30 times more than the Big Qualicum River produces per square metre. In terms of weight, it is 15 times. In terms of water use, we were using less than three percent of the river flow.

So this time, we seemed to have got things right, except that the fish had been clearly overstocked. It would be of great interest to repeat the work with smaller densities of fish to see what size they would attain. Given the thermal regime we had, with ample food, the fish were theoretically capable of reaching a size of 45 grams.

These smolts were indeed smolts. They accepted salt water in saltwater tests, whereas the parr that remained behind, of which there were several thousand, could not accept salt water. The smolts were collected in downstream traps near the river mouth at Qualicum when they left.

To summarize what I have said: in the first trial, we had 10,000 tagged fry and a discharge of 15 cfs (0.4 m^3). The steelhead became emaciated and diseased.

In the second trial, a discharge of 0.14 m^3/s, was used and the outcome was 1,200 smolts at 15 grams mean weight, and 3,000 parr. The yield of smolts was 31 times the number, or 10 times the biomass, per unit area of river production. Channel discharge was 2.6 percent of the river discharge.

I now want to talk about an allied subject, stream enrichment. If we got everything right in our ideal stream, there is still the question: can we increase food? It is sometimes debated that food is not limiting for salmon in streams. I think that often, in fact, it is. For example, salmonids respond to mild pollution. It is not difficult to demonstrate that increases in food are frequently beneficial to salmonids in streams.

In our enrichment work, we have not gone as far as the provincial Fish and Wildlife Branch. We wanted to have a fairly modest objective, which was to establish if fish food organisms -- insects which live in the gravel -- respond to organic enrichment, i.e. to the addition of cheap common materials such as cereal grain or soybean; and if they did respond, what was the magnitude of this response in terms of numbers and weights.

The insects that live in gravel tend to be very small. In fact, the most abundant ones were just visible to the naked eye. But as they get larger and approach the time when they will leave the water, they then become important food items for fish.

We set up 12 parallel troughs in the channel and placed medium-size gravel in them. We allowed the troughs a couple of weeks to become colonized by insects. In addition, we wanted to know what would leave the troughs. It is one thing to see the response in terms of standing stock of benthos, but suppose the insects were drifting constantly out of the troughs. This, of course, is when they become available to fish. We wanted to know if we could measure that. In each trough, therefore, we had a plastic pipe leading to a collecting bucket.

In every second trough, we put soyabean. We carried out five experiments, but I shall talk about just one. We had controls and treatments. The purpose of the troughs was to look at variation within the controls and within the treatments. It is only from knowledge of that variation that one can assess the difference between the untreated and the treated gravels.

We left the grain or soyabean in these troughs for a month. At the end of that time, the material is mushy and generates bacteria that is appropriate food for many of the insects. We collected the material simply by putting a plankton net over the end of the trough and stirring up the gravel with a garden fork, and collecting this massive, mushy material in a net. In it, of course, are thousands of insects ranging in size from minute ones to those a couple of inches long.

This is extremely troublesome material to come to grips with. There is no more difficult material to assess than solids suspended in a slurry. To tackle this problem, we settled the contents of a net into a bucket of water, on the bottom of which were about 80 upright 3" x 1" glass tubes. We let the stuff settle overnight. What we had done was subdivide the whole sample at one time into about 80 roughly equal portions, ignoring what settled between the tubes. We pull out tubes and examine them under a microscope. If we find that we need high counts of insects, we just keep drawing tubes until we have enough. Statistically, it is a very powerful approach.

We found that the invertebrates that responded most to enrichment were the chironomid midges, particularly the large red ones (that is of interest because they are the ones that are most tolerant of oxygen debt), and the worms--the tiny colorless worms that live in fresh water.

The midges are valuable fish food organisms. The worms are not. Salmonids do eat worms, but this is relatively rare and not of much consequence. However, worms are of consequence to other invertebrates, because midges and other insects prey on them; so we are indirectly contributing to fish food by this response.

The response in numbers after a month of treatment was 1.5 to 2.9 times. The response in weight was 1.4 to 1.9 times. To our surprise there was no difference in the insects drifting from the troughs in the treatments and the controls. There are different ways of viewing that result. One is that the reason why insects drift is they are looking for a better place to live. If there is ample food, they stay where they are. That is one explanation.

Another explanation is that the amount drifting was simply masked by insects coming in from upstream; i.e. we could not detect the additional numbers generated by the troughs. If you want an opinion, I would favor the second explanation.

We had demonstrated, then, that fish food organisms respond to organic enrichment, and these would become available to fish when they emerge. The groups that responded were mainly the chironomids and the oligachaetes.

Both these experiments have been published in different issues of the Canadian Journal of Fisheries and Aquatic Science in 1983, so if anybody wants to get more details, the information is there.

In conclusion, I suggest that field manipulations of stream features are one way by which we can build our understanding of what goes into the making of salmonid production in streams. I have attempted, in these two examples, to isolate features of importance, manipulate them and get a result.

I think if we maintain a dialogue between experience of whole natural systems and manipulative experiments over which we have control, so that we can make assessments, then we can build our understanding, and on this we can make judgements on problem situations.

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STREAM RESTORATION IN THE LOWER MAINLAND - BAKER CREEK, A CASE HISTORY

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The Lower Mainland of B.C. supports a population of more than one million people and, as a result, it is highly urbanized. The Lower Mainland also contains numerous salmon streams, many of which are extremely small but highly productive and collectively make a significant contribution to local fisheries. Often such streams are no larger than a roadside ditch, however, the habitat values are very complex and delicately balanced making them extremely vulnerable to external impacts. Restoration of such streams is difficult under any circumstance.

Our unit is heavily involved in protecting small streams in the Lower Mainland due to the magnitude of urban development and we are often required to react quickly to problems generated by unforeseen circumstances. Such was the situation at Baker Creek in Coquitlam.

Baker Creek is a small urban stream of only a few miles in length originating from a local area known as Mary Hill and flowing into the Fraser River just upstream from the Coquitlam River and the Port Mann Bridge. The Department of Highways had been planning a new bypass route to connect the freeway at Port Mann with the eastbound portion of the Lougheed Highway at the Pitt River. A portion of the route would skirt around Mary Hill along the foreshore of the Fraser River crossing Baker Creek near its mouth. Negotiations with MOTH were carried out in the routine manner and approval was given to the plan on the basis of a single stream crossing. The plan was promptly put on the shelf for a few years while other highway priorities were addressed and when its turn finally came, some small changes were made without DFO knowledge. These changes included a re-alignment of the highway at Baker Creek which now placed the roadway on top of the stream rather than across its mouth. This change was not made known until the contract was awarded and the contractor was ready to start construction, hence, an urgent situation developed in which a stream would require complete diversion and reconstruction in one of its most productive reaches.

The affected portion of Baker Creek was measured to be approximately 700 feet long of which 50% contained low gradient swamp habitat with extensive streambank vegetation and the other half consisted of a medium gradient channel in an open field with undercut banks and low level cover. Fish use in this section of Baker Creek was restricted to rearing only as spawning areas further upstream were not affected. A small tributary stream entered Baker Creek about mid-point in the affected section of the original channel but did not provide additional instream habitat due to its size but did contribute a constant flow of water to the lower system.

As construction of the highway was to start immediately, insufficient time was available to undertake studies of productivity or other detailed habitat evaluations and quick decisions had to be made in order to meet very tight schedules. Such decisions are often imposed on DFO area staff due to the frequency that similar situations routinely occur in this highy urbanized region and quick action had to be taken to resolve the issues at hand. The process took the following steps:

1. Determination of the amount of habitat to be lost due to displacement by the roadway.
2. Location of an area suitable to develop replacement habitat of similar dimensions.
3. Design of the new channel within the area provided in terms of general layout.
4. Construction of the channel and development of habitat features.

The first step involved measuring the existing channel length and estimating the amount of suitable habitat within that portion of stream. This step was relatively simple due to extensive surveys which had been undertaken by MOTH during the design phase and the singular use of the stream by fish.

The second step was more difficult due to requirements for a frontage road on the river side of the highway and the height of the roadway through the area which combined to eliminate the possibility of locating the new stream on one side and severely reduced the available area on the other. In order to obtain additional area, negotiations had to be held with the property owner adjacent to the highway on the upland side so that permission could be granted to divert the stream onto private land. A fair agreement was reached without much difficulty and a minor amount of encroachment was permitted.

Step three involved walking the area and placing stakes in the ground to locate the proposed new channel alignment followed by a survey to permit review in the office. A number of changes were made due to topographical restrictions and the final product was drawn schematically before it was transferred to the ground. The final design resulted in a total of 700 feet of new stream channel on the upland side of the highway suitable for rearing and a 250 foot channel on the riverside designed for migration only. Access through the new highway grade was maintained by two large culverts constructed on a level grade and installed slightly below the stream bottom to maximize fish passage.

The fourth and final step was the most critical and involved a design-as-you-go procedure in which habitat features in the channel were created as opportunity arose utilizing where possible natural features such as logs, root wads, erodable banks and existing foliage. This step also involved extremely complex phasing of new channel construction to ensure that the activities were isolated from the existing stream and that fish were salvaged from these areas prior to channel diversion. This work was carried out systematically by proceeding section by section and completing each new area before the actual diversions took place. All work during this stage of the operation involved constant attention by a DFO staff member, Rob Elvidge, who orchestrated the activities and final arrangement of habitat features at the site. This close personal attention was the most effective means of developing the design of the new channel as it allowed us to capitalize on site specific opportunities as they arose such as retaining old stumps, logs, foliage and large boulders which would normally be removed from the work area. In addition, slight modifications in the channel alignment could also be engineered to take advantage of subtle topography changes to reduce the depth of excavation, steepen banks to encourage undercutting, or avoid undesirable soil conditions. Immediately following excavation and stabilization, a re-vegetation program was undertaken with the use of aquatic as well as terrestrial plants.

Upon completion, the new channel gave the appearance of a stable, meandering stream which had been formed naturally. The undercut banks, large instream debris and streamside vegetation produced sufficient habitat diversity and cover to provide initial accommodation for the rearing salmonids which currently utilized the system. Because the new channel was engineered to take advantage of natural conditions, the next storm event quickly completed the task of shaping the stream and produced a very high quality section of fish habitat which could not be distinguished from that found in many other urban systems.

This typical example of stream restoration is repeated frequently in the Lower Mainland due to the magnitude of development produced by population demand. We have found that this technique of "design-as-you-go" works well provided that an experienced person is available at the site to direct operations and a general formula for total habitat value has been prepared for use as an overall blueprint. The concept of developing each habitat feature to take advantage of site conditions and encourage rather than prevent natural changes in the channel produces extra dividends by accelerating the ecological process and maximizing productivity in the minimum amount of time. Maintenance of the facility is also substantially reduced because change in the channel is anticipated and can be accommodated within the general framework without threatening any particular component. In other words, natural processes are called upon to perform some of the work and provide the finishing touches.

The Land Use Section of the Habitat Management Unit in the Fraser River Division is confronted by similar circumstances often in the course of normal operations, and continues to address the problems in the manner described above. It has proven to be an effective means of habitat restoration and one which will improve with time.

SOME DIFFERENCES BETWEEN COASTAL AND INTERIOR STREAM ECOSYSTEMS AND THE IMPLICATIONS TO JUVENILE FISH PRODUCTION

David Bustard
Consulting Fishery Biologist

INTRODUCTION

The hydrological characteristics of a stream play a major role in determining its productive capability. Most of the detailed stream studies on juvenile salmonid populations have been undertaken on coastal systems where streamflow is influencd predominantly by rainfall (e.g. Carnation Creek, Keogh River, Clearwater River and Alsek River). There is a certain amount of agreement that in many of our coastal streams, the low summer flows and winter freshets play significant roles in determining eventual smolt production for those species which continue to rear in streams post-emergence (Burns, 1971; Giger, 1974; Mason, 1976; Cederholm and Scarlett, 1981; Holtby and Hartman, 1982). The importance of low summer flows versus winter freshets probably varies depending on the size and flow characteristics of the particular system.

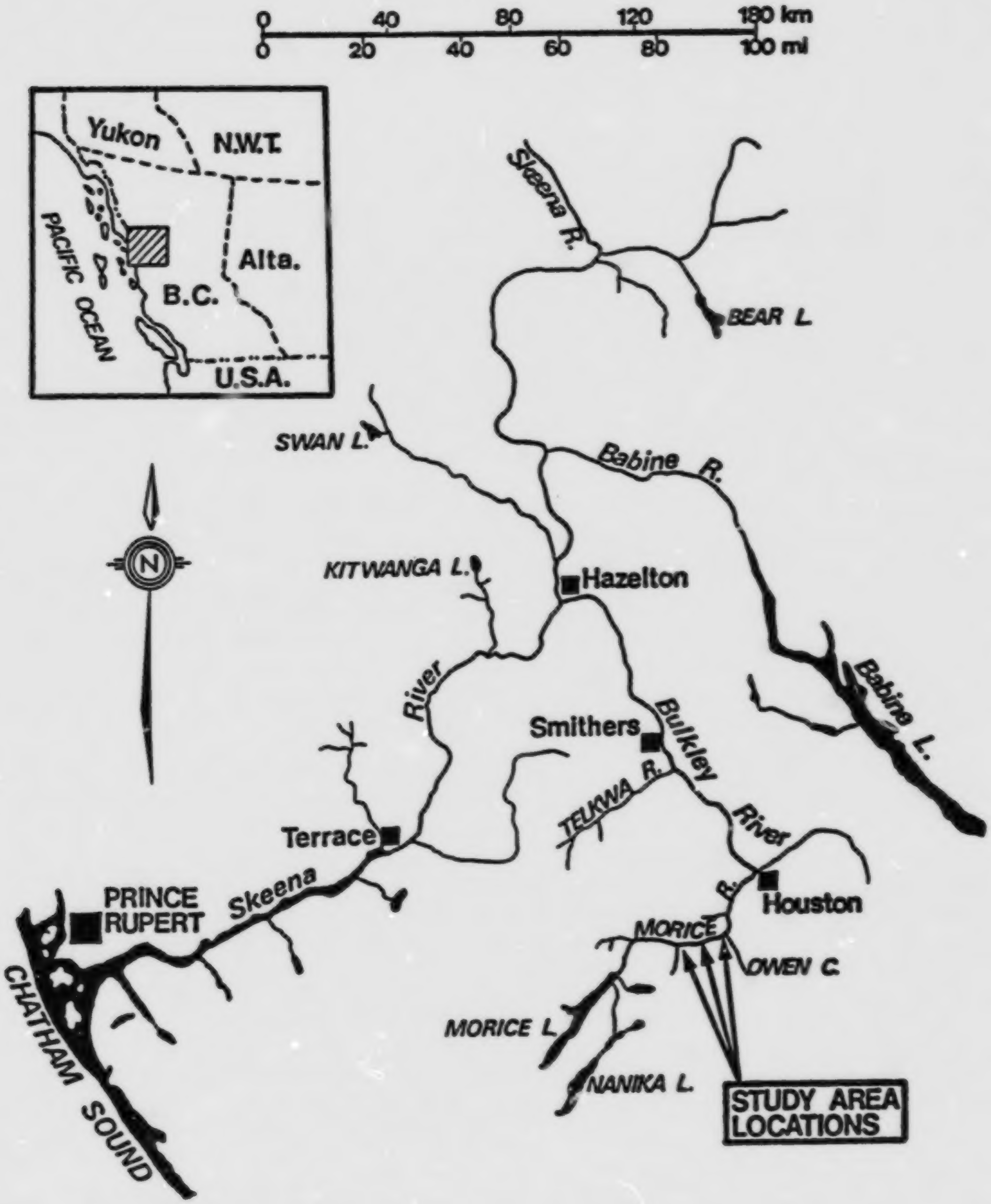
While many of the small interior watersheds without significant snowpack or glaciers are subject to very low summer flows similar to those observed in coastal streams, some of the larger interior systems, such as the Morice and Telkwa Rivers (Figure 1), do not experience these low summer flows or winter freshets. Instead, the lowest flows occur during the winter, and the freshets occur in the early summer (Figure 2). The summer flows remain high from May through to late October as a result of snowpack and glacier melt and fall rains which may or may not be buffered by lake systems. From late November onward, nearly all precipitation is in the form of snow, and the rivers' discharge drops progressively through the winter. By late March and early April, flows are consistently at their annual lows. In the Morice River, for example, these late winter flows are typically about 20 percent of the lowest summer-fall discharge.

This altered pattern of high and low flows has led to some interesting differences in juvenile mortality factors and to apparent adaptive responses to overcome some of the limitations imposed by low winter flows and summer freshets. It should be emphasized that the Morice and Telkwa Rivers are not representative of all interior streams. They possess more side channel habitat than most. Because of this, they serve well in illustrating differences which can occur between coastal and interior streams. As well, many of B.C.'s coastal streams have run-off regimes somewhere between the coastal and interior examples presented in Figure 2.

WINTER LOW FLOWS

Juvenile sampling programs throughout the Morice and lower Telkwa Rivers indicate that a multitude of side channels provide valuable rearing habitat for coho and chinook salmon and steelhead trout. For example, approximately 150 km

Figure 1.
Location of Morice River and Study Area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Skeena R.
BEAR L.
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Babine R.
KITWANGA L.
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River
Smithers
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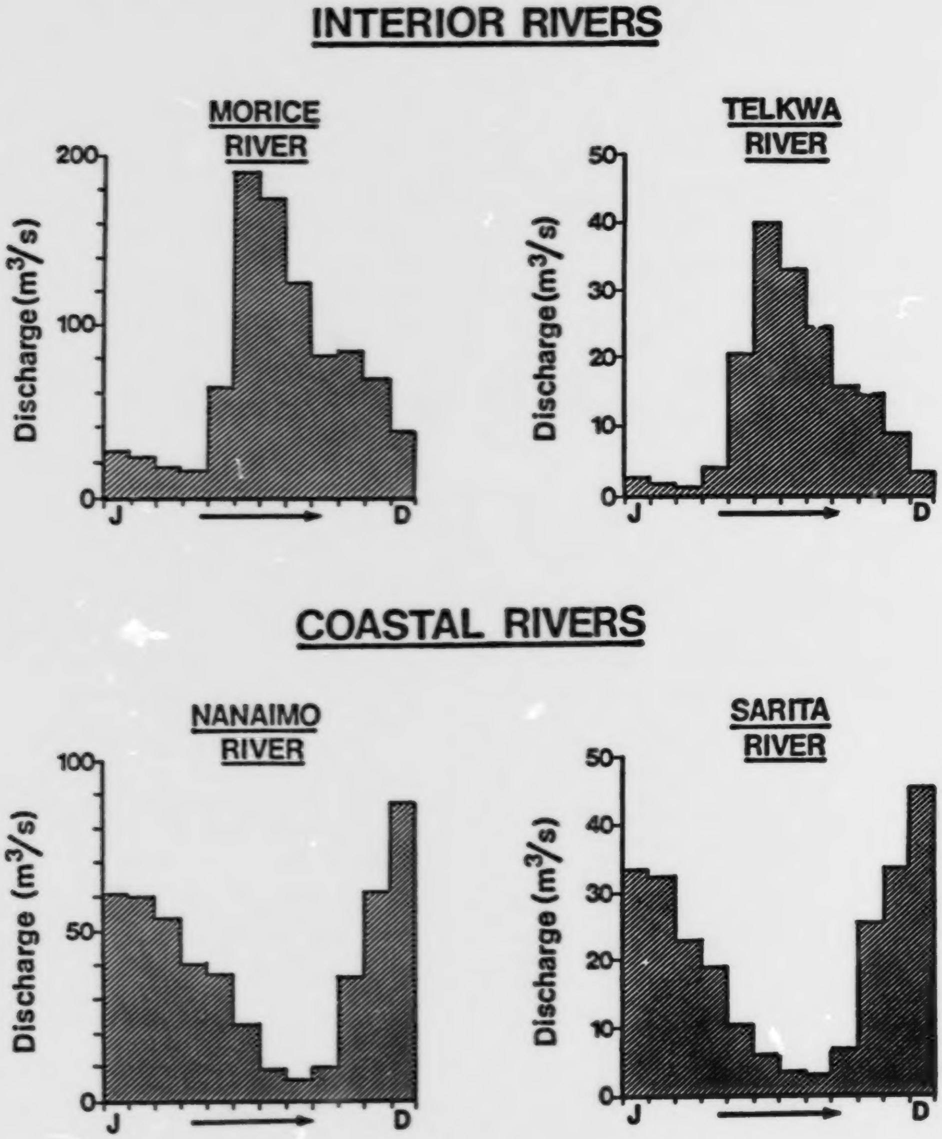
Terrace
PRINCE RUPERT
Skeena
R.
Houston
MORICE
OWEN C.
MORICE L.
NANIKA L.
STUDY AREA LOCATIONS
CHATHAM SOUND

Figure 2.

Mean Monthly Discharges of Two Interior and Two Coastal Rivers



of side channels account for more than half of the total rearing in the Morice River, excluding tributaries which are used by coho salmon and steelhead trout. As flows decline throughout the winter, many of the channels either dry up or are reduced to a few isolated pools. Since young fish in these channels are generally inactive for much of the winter, they are not subject to the territorial displacement that occurs in coastal streams with declining summer flows. However, conditions associated with low winter flows can result in significant mortalities.

To determine the magnitude of overwinter losses in side channels, population estimates were conducted at four representative side channels in the Morice River during late fall of 1981. Fish movements in and out of these channels were monitored by traps maintained until freeze-up, and fish populations were reassessed in the spring prior to the freshet.

Results from the seven weeks that the traps were maintained indicated that when the data were combined for all of the channels, there was less than a one percent change in steelhead trout fry or parr numbers, no net change in coho numbers, and a movement out of approximately 20 percent of the estimated chinook salmon population. These results suggest that most juvenile salmonids remain in the vicinity of rearing areas utilized during late October, throughout the winter.

In total, in the four sections of side channel, it was estimated that there was a fall population of 3,517 juvenile salmonids comprised of 52 percent coho, 30 percent steelhead fry, nine percent steelhead parr and nine percent chinook fry. Other fish species comprised less than two percent of the total and have been omitted from the sample. The mean overwinter survival for all species combined was 43 percent (Table 1). Steelhead trout fry and parr had the poorest survival at 21 percent and 30 percent respectively, while chinook and coho had the best overwinter survival, averaging greater than 50 percent.

Table 1. Overwinter Survival by Species Based on October 1981 and April 1982 Population Estimates Combined for the Four Side Channels.

	Estimated Population*		
	October	April	% Survival
Steelhead Fry	1,053	317	30.1
Steelhead Parr	328	68	20.7
Coho	1,824	943	51.7
Chinook	312	198	63.5
All Species	3,517	1,526	43.4

* October population estimates have been corrected for movements in and out of the study area.

While these estimates of overwinter survival may be at least roughly comparable to those found in other studies, the observed causes of mortality are not. A variety of conditions were observed in these side channels which were contributing to overwinter losses. These included: stranding leading to suffocation and freezing of juveniles; low dissolved oxygen levels; predation.

Stranding and Freezing

Table 2 shows the change in wetted areas in the four side channels between October and the following April. The last column presents the overwinter survival estimates for each of these channels.

The poorest overwinter survival occurred in the two channels which had the least percentage of wetted area remaining in the spring. In the side channel with the highest survival, nearly 45 percent of the channel remained wetted throughout the winter.

Small inflows of groundwater during the winter into Side Channel D and the lower end of Side Channel C resulted in far less reduction of wetted areas and greater overwinter survival in these two channels, compared to the other channels which did not have significant groundwater inputs.

Stranding of juveniles into isolated pools which subsequently dewatered was observed in three of the four side channels. For example, Side Channel B decreased in wetted area from 8,600 m^2 in late October to 300 m^2 in early April. A total of 78 juvenile fish were found dead in dewatered sites during several visits to this channel in early April.

Clear, very cold periods during the early winter and again in the spring when shallow pools are not covered with ice and insulated by snow can result in these pools freezing solid. This phenomena was observed on a widespread basis throughout the Morice River and several tributaries during late November 1979, and appeared to cause substantial juvenile fish losses in that year. Similarly, ice formation during the early winter can be widespread and may have severe implications to juveniles wintering in tributaries and along the river margin.

Table 2. Percentage of Side Channel Area Remaining Wetted in April Compared to Overwinter Survival in the Four Side Channels.

	Wetted area (m^2) October	Wetted area (m^2) April	% Remaining Wetted in April	Overwinter Survival
Side Channel A	2,217	20	0.9	33.7
Side Channel B	8,632	264	3.1	30.2
Side Channel C	1,244	103	8.3	46.4
Side Channel D	3,257	1,455	44.7	59.8
All Side Channels	15,350	1,842	12.0	43.4

Low Dissolved Oxygen

A second factor responsible for overwinter mortalities was oxygen depletion. Two of three large pools remaining in Side Channel B had winter kill of over 100 juvenile fish. For example, one pool, with a depth of 40 cm had a dissolved oxygen level of less than 1.0 ppm in early April. The remains of fish in this pool were badly decomposed, suggesting that mortalities had occurred earlier in the winter. It is probable that the concentrations in the pools decreased as a result of bacterial decomposition of the litter, and of the dead fish. This, in conjunction with little or no exchange of water in the pools, and no reaeration due to ice cover, probably led to the very low oxygen levels observed. There is a growing body of evidence that suggests natural oxygen depression to levels below 5 ppm in the late winter is a widespread phenomenom in northern environments (Schreier et al, 1980).

Predation

Predation on juvenile fish, particularly by birds, is a third factor which may significantly decrease overwinter survival. In the Morice River, large concentrations of fish exposed in shallow pools after the ice melts in April are very vulnerable, particularly to a sizeable population of mergansers present on the river in the spring. For example, the population of fish in a small 10 m^2 pool declined nearly 60 percent in a two-week period in early April. Presumably, most of the 106 fish lost were taken by predators.

SUMMER HIGH FLOWS

Many coastal and interior streams also have the timing of their high flow events reversed. The highest flows in many of B.C.'s interior streams generally occur during the main snowmelt period from May through July. As well, short duration high flows resulting from rain-on-snow during the fall may exceed the highest summer flows during some years. There is no good documentation of the implication of these long duration high flows on juvenile salmonids. Carnation Creek data suggest that coho fry may be physically displaced during high flows to the point of underseeding during certain years (Holtby and Hartman, 1982). Observations in the Morice River during the freshet suggest that much of the mainstem river is rather inhospitable during this period and juveniles tend to be found in backwaters, side channels and any available areas where velocities are reduced and conditions moderated.

Studies in several coastal rivers have identified distinct movements by various species of juvenile salmon and trout associated with freshet flows. For example, Cederholm and Scarlett (1982) report movements of juvenile coho salmon, cutthroat and steelhead trout into run-off tributaries of the Clearwater River during the fall coinciding with fall freshets, and subsequent downstream movements in the spring. Everest (1973) indicates that large numbers of juvenile steelhead trout move out of the mainstem Rogue River into tributaries to avoid the severe freshets which may accompany winter rains.

Interior rivers may also have similar movements between the mainstem river and tributaries, but these movements occur at different times of the year. In many Idaho streams, 50 percent or more of the juvenile salmon and steelhead trout leave tributary streams during the fall and winter months, and return upstream the following spring (Chapman and Bjornn, 1969). In B.C., there is a substantial out-migration of young steelhead from the Deadman River into the Thompson River during the late summer and fall periods (Starr, 1979).

At the same time, data from the Kispiox River (Tredger, 1983) and observations on the Morice River suggest a movement of some juveniles into tributary streams during the early summer. This may be a response to the snowmelt freshet and the generally more suitable conditions in the lower elevation tributaries during the main run-off period. These observations suggest that in interior streams there may be a movement by some fish into tributaries during the early summer freshet with a subsequent return to the larger river systems to overwinter.

The concept of juvenile coho moving into pond and slough areas adjacent to stream systems has been well documented in several coastal streams (e.g. Cederholm and Scarlett, 1981; Tschaplinski and Hartman, 1983). Immigration into these off-channel sites typically occurs from September to December, and coincides with freshets resulting from fall and winter rains. Movement out of these sites normally occurs from February through June. Interestingly, juvenile coho in interior rivers undertake similar movements into pond areas, but at an entirely different time of year.

Results from traps maintained at the outlet of a 0.5 ha pond adjacent to the Morice River indicate that a movement of fry and yearling coho occurs into the pond from the mainstem Morice River during May and June, coincident with the beginning of the snowmelt freshet in the Morice River (Figure 3). This is also the timing of coho smolt movements out of the ponds. Nearly all movements for the year appear to be concentrated in this one-month period in the spring which is the only period of consistent access into the pond. A total of 285 coho salmon smolts were captured in the outlet of the pond (Figure 4). These smolts were on average 20 mm larger than coho smolts captured in side channels of the Morice River during the same period. This pond area, and probably many other similar ponds, provides a refuge for juvenile coho from the snowmelt freshet and an apparently very productive summer rearing habitat. Fish overwinter in these areas, and leave as smolts the following spring.

CONCLUSION

In conclusion, it is essential that we understand the basic ecology of the target species which we are attempting to enhance. Conventional techniques often based on research in coastal watersheds may be totally inappropriate in some interior streams. The eventual smolt production from a system may be governed by entirely different sets of principles occurring at different times of the year. Low winter flows, ice conditions and groundwater all play probably a far more significant role in interior river systems than in coastal streams. As well, seasonal shifts of juvenile fish between tributaries and mainstem rivers may be occurring at different times of the year than in coastal streams. The mainstem rivers may serve as more important overwintering areas for juveniles than in coastal systems. These differences should be incorporated into habitat evaluation and planning for instream improvement projects in interior rivers.

Figure 3.

Timing of Juvenile Coho Pond Migrations and Discharge in the Morice River, 1982

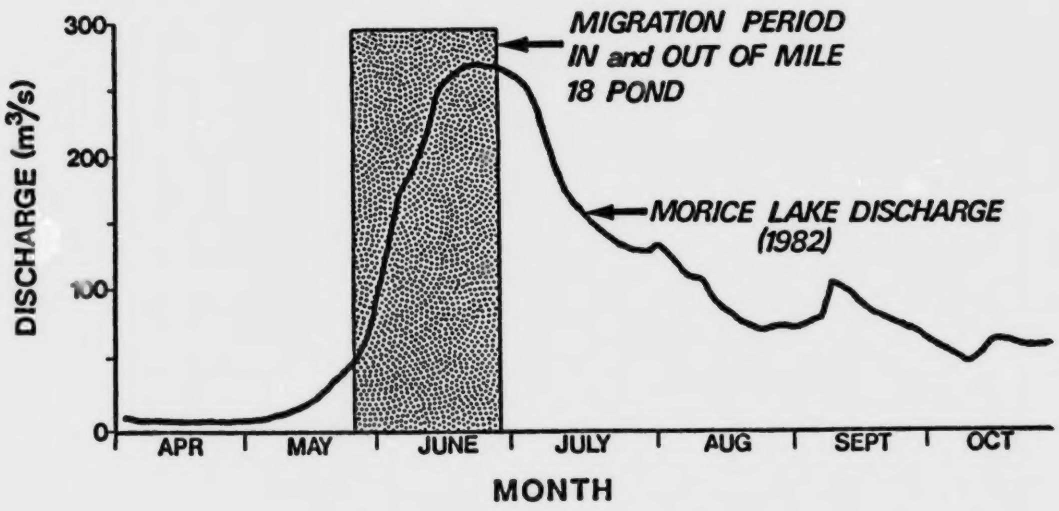
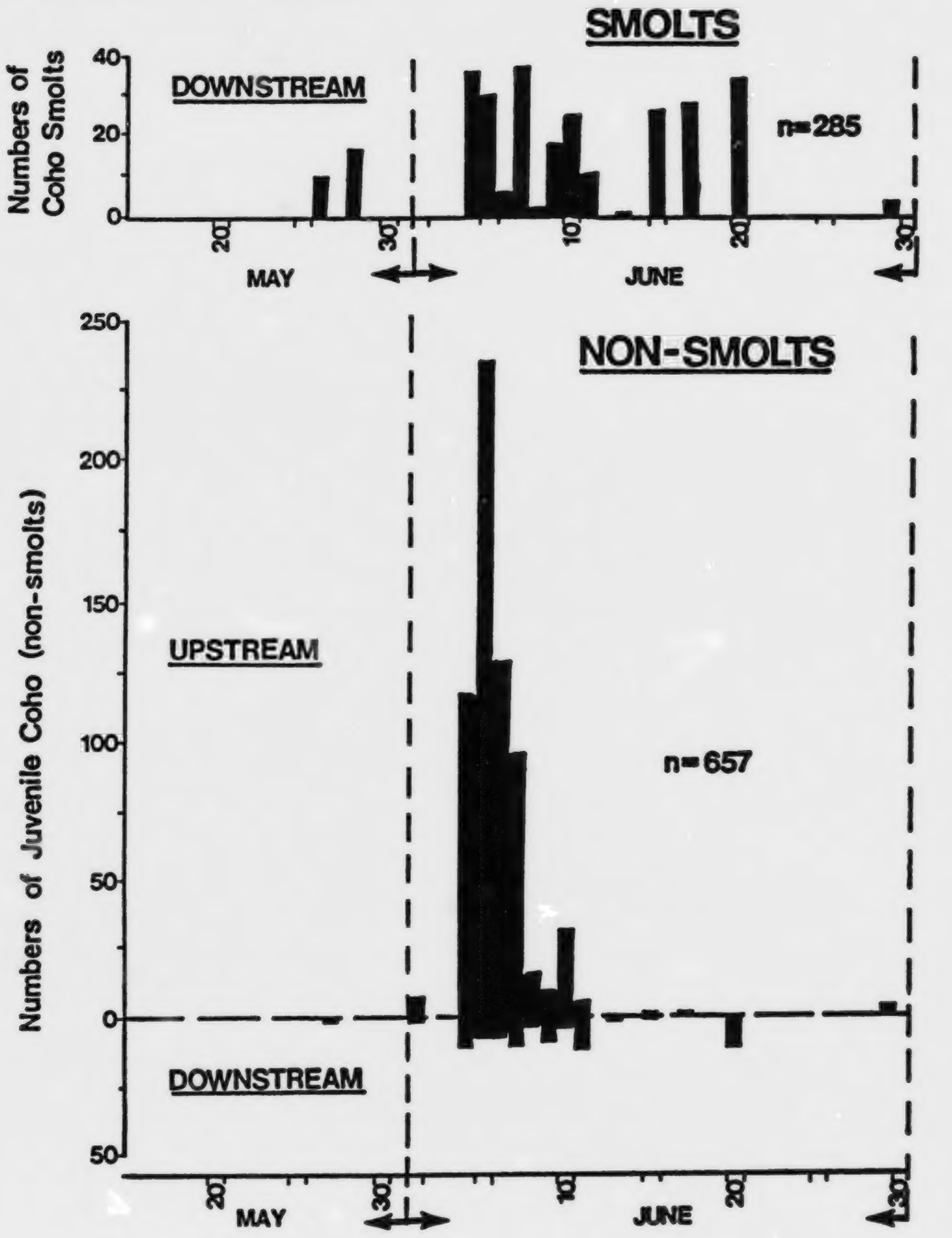


Figure 4.

Movement of Juvenile Coho through Traps Located at the Outlet of Mile 18 Pond



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FISH HABITAT ENHANCEMENT AND EVALUATION IN THE FISH CREEK DRAINAGE

David A. Heller[1],
Fred H. Everest[2], James R. Sedell[2],
and John R. Wolfe, Jr.[3]

Fish Creek is a major fifth order tributary of the Clackamas River in northwest Oregon. The drainage area is 106 km^2 and is wholly within the Mount Hood National Forest. Fish Creek is generally steep (four to five percent) and boulder dominated. The floodplain is typically narrow (40 to 60 m) and valley slopes steep (60 percent plus.) The stream is characterized by wide seasonal flow fluctuations. Low flows, near the mouth, average about 0.5 m^3/s while annual high flows often exceed 100 m^3/s. The stream supports three anadromous species; spring chinook and coho salmon and steelhead trout (winter and summer runs). A total of about 18 km of habitat, for these species, are provided in Fish Creek and its major tributary, Wash Creek.

Forest Service management responsibilities include the maintenance and enhancement of fish habitat. Fish Creek management objectives emphasize: the maintenance of riparian habitat, with special consideration given to bank stability, large woody debris and stream shading; the maintenance and improvement of fish habitat, with special emphasis on anadromous spawning and rearing habitats; and the quantitative monitoring and evaluation of habitat management activities, especially anadromous enhancement projects.

In 1982 - 83, a five-year enhancement and evaluation program was initiated on Fish Creek. Enhancement work is headed by the Estacada Ranger District. Evaluation efforts are accomplished by the Pacific Northwest Forest and Range Experiment Station. The program is jointly funded by the U.S. Forest Service and the Bonneville Power Administration (BPA). BPA funds are part of the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife program.

Baseline information on existing habitat and fish species distribution came from 1976 Forest Service surveys. This was updated and significantly expanded by physical and biological baseline sampling of the evaluation program. Reconnaissance level surveys were used to delineate total accessible habitat and total spawning habitat, by fish species. Description of Fish Creek rearing habitat was developed by compiling intensive sampling results from five, 0.5 km representative reaches. Sampling included measurement of the surface area and water volume for each of five distinct habitat types. These included: riffles, pools, side channels, alcoves and beaver ponds. Total area and volume, for each habitat type, in the accessible areas of Fish Creek was then estimated. Fish population estimates were developed separately for 36 habitat units (one habitat unit is one pool, riffle, alcove, side channel or beaver pond). These were then extrapolated for the basin on the basis of previously determined area and volume for each habitat type (Figures 1 and 2).

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[3] John Wolfe, Fish Biologist, Mount Hood National Forest, Estacada Ranger District.

Enhancement project planning has focused on the habitat requirements, by life history stage, of each of the stream's anadromous species. In 1983, no passage enhancement work occurred. Currently, about 15 to 20 km of habitat are blocked by major waterfalls and an additional 6 to 10 km by road culverts. Future passage projects are likely.

Spawning habitat improvement was a major focus of work in 1983. Information revealed spawning habitat for spring chinook salmon was likely limiting. Fish Creek was found to have only 190 m^2 of suitable chinook gravel. In 1982, 86 chinook redds were inventoried. This allowed only about 2.2 m^2 per spawning pair. Substantial superimposition was also noted. Large amounts of excess rearing habitat are believed to exist downstream in the mainstem Clackamas River.

To increase available chinook spawning habitat, 18 cross channel and three half channel, boulder berms were installed (Figure 3). These were designed to create hydraulic conditions favorable for the deposition of suitable-sized bedload materials carried by the stream. Design of the berms was similar to that used in five successful proto-type structures installed in 1981. Berms were constructed with a large, track mounted backhoe. Each involved repositioning of large numbers of boulders found in the vicinity of each berm site. Base level boulders were selected to equal or exceed the size of similar, stable boulders in the area. Berm configuration was typically a downstream pointing V. Total berm length averaged 20 to 30 cm. Berm height was limited to 0.6 to 0.8 m above the stream bed. This was to minimize resistance to the highest flows. Installation was limited to two types of sites; straight, low (two percent) gradient channel sections and the tail out area of relatively large, bedrock controlled pools. Site selection was considered critical for the long-term survival of these structures.

It is estimated that a minimum of 200 to 300 m^2 of additional chinook spawning gravel will be recruited by the berms. This will more than double what is currently available, for this species, in Fish Creek. Average cost, per structure, was about $350. Project life is estimated to be 15 years.

An unusal project to improve coho rearing habitat was also completed in 1983. It involved development of an off channel rearing pond. Baseline sampling of edge (alcoves and side channels) and quiet water (pools and beaver ponds) habitats indicated they constituted less than 20 percent of the stream-wetted area (100,000 m^2) used by rearing coho. Population sampling indicated disproportionately high coho numbers and biomass in one habitat type, the beaver pond. Based upon available coho spawning habitat, it was felt that with adequate rearing area, Fish Creek could produce at least 12,000 to 15,000

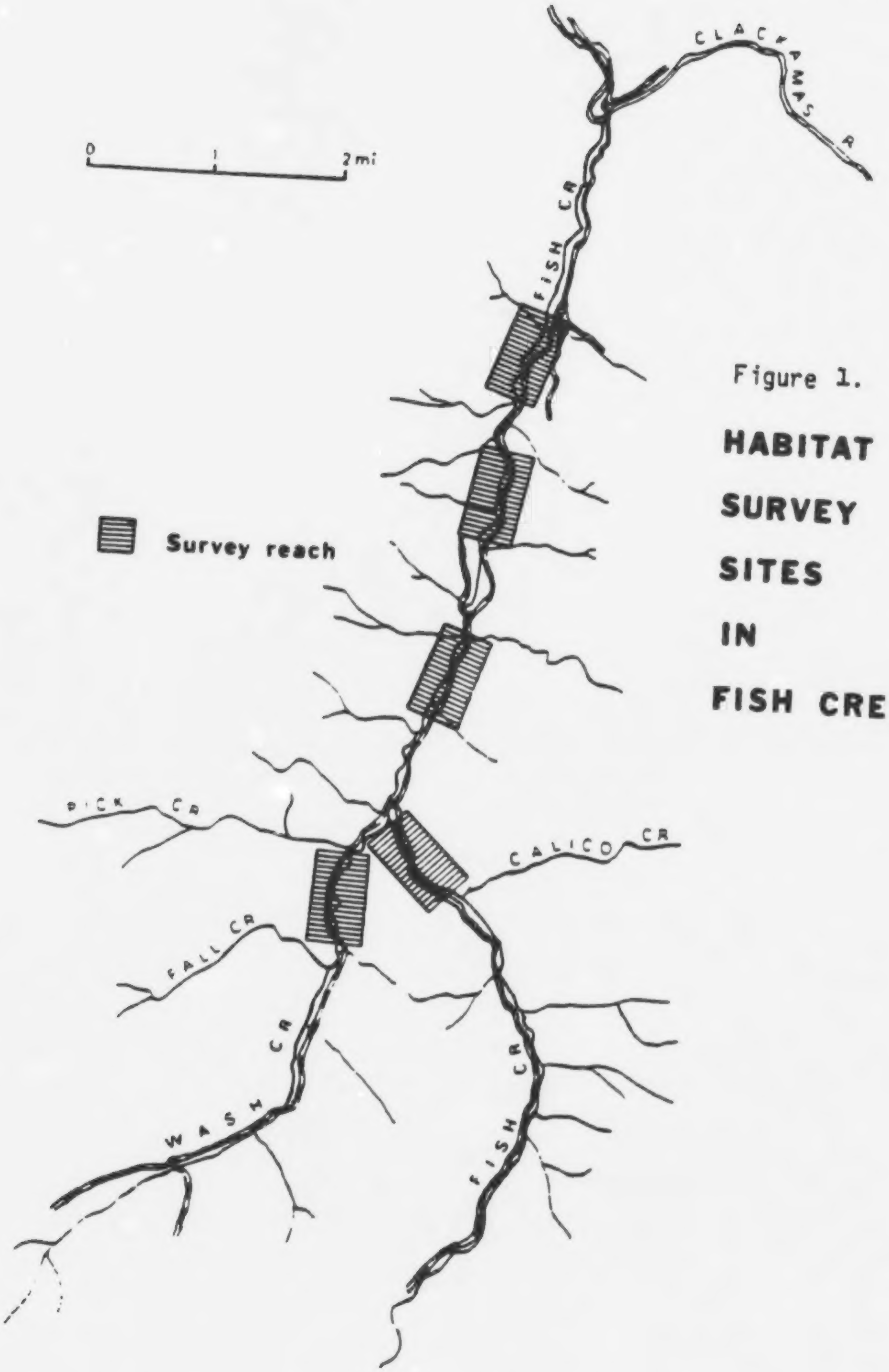
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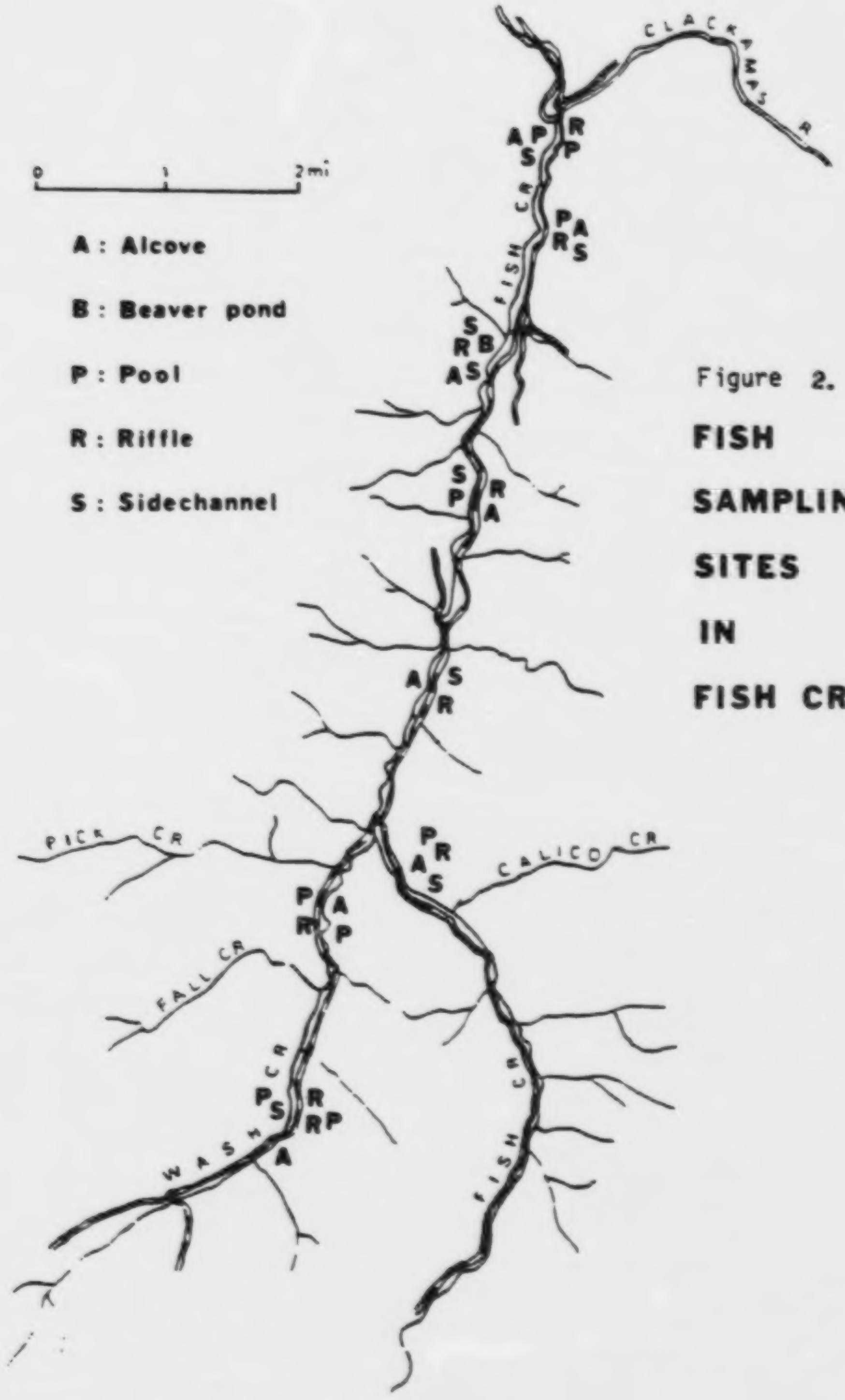
Figure 1.

HABITAT SURVEY SITES IN FISH CREEK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B : Beaver pond
P : Pool
R : Riffle
S : Sidechannel
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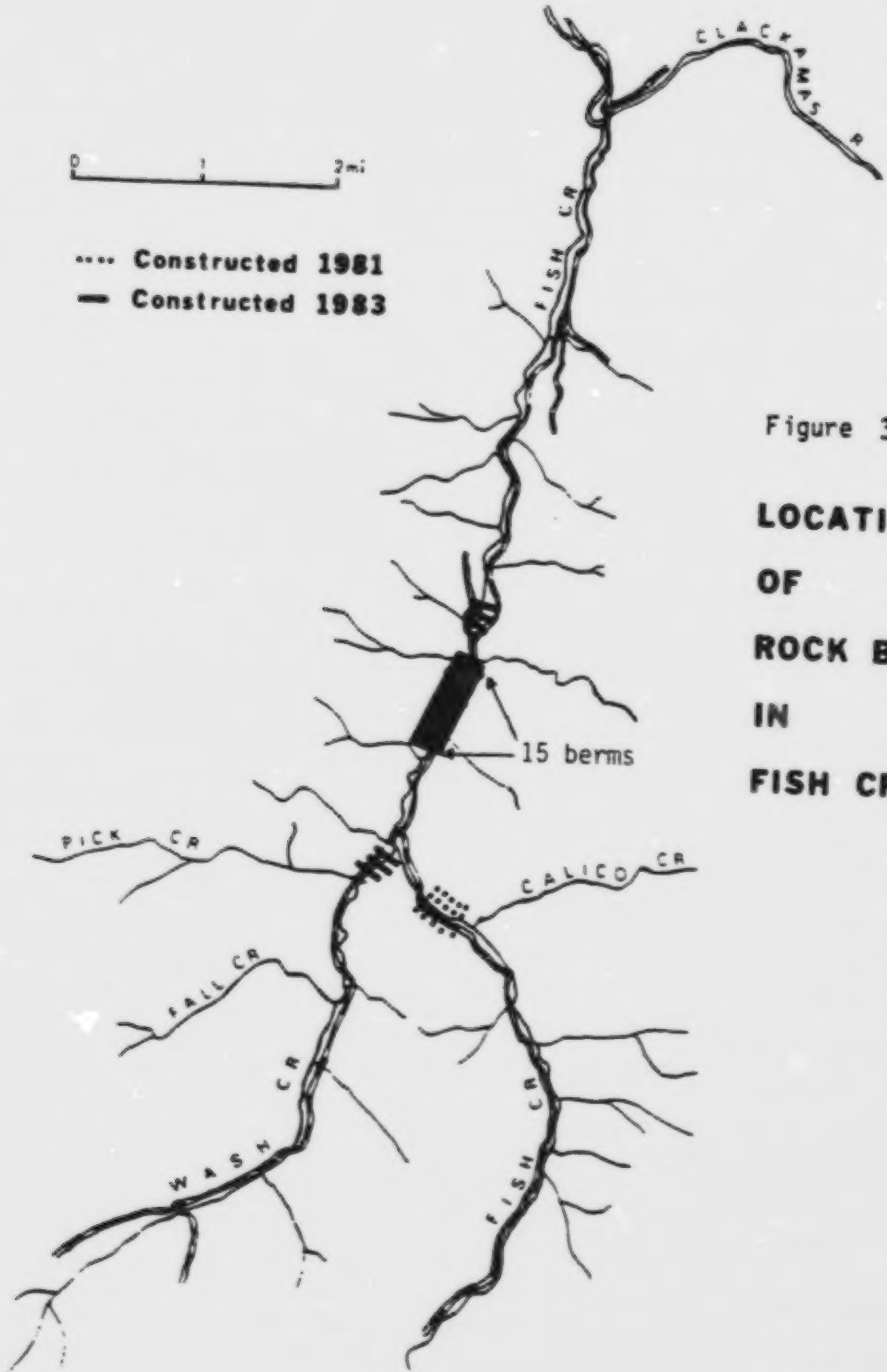
Figure 2. FISH SAMPLING SITES IN FISH CREEK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FISH CR
15 berms
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CALICO CR
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WASH CR
FISH CR

Figure 3.

LOCATION OF ROCK BERMS IN FISH CREEK

smolts annually instead of the current 4,000 to 8,000. Although not quantified, it appeared that overwintering habitat for all anadromous species was also in short supply.

Project work included providing fish access and a perennial water supply to a vernal beaver pond, located on a floodplain terrace (Figure 4). The pond, which was normally dry from June to September, has a surface area of about 0.5 ha and a volume of about 3,600 m^3 when full. To provide summer flow, a gravity feed pipeline was run 135 m from Fish Creek to an abandoned overflow channel. Within 70 - 80 m the channel enters the pond. The 25 cm diameter pipe will provide flows of about .035 m^3/s to the pond. To further augment flows, and to provide about 20 m^2 of spawning habitat, a small, valley wall tributary was also diverted into the pond. Finally, to provide year-round access from Fish Creek to the pond, a four-step, wooden fish ladder was installed. This was sited at an outlet excavated at the upper end of an old levee and oveflow channel. To facilitate evaluation, a water-driven, rotating fish screen was placed at the head of the ladder. This screen diverts both up and downstream migrants into one of two screen trap boxes located adjacent to the ladder (Figure 5).

Total cost for planning and development of the pond was about $25,000. The project will provide an additional 3,600 m^3 of beaver pond type habitat in Fish Creek. This is a 29 fold increase in this preferred coho rearing habitat. Assuming future production, commensurate with the one natural beaver pond, 7,200 additional juveniles and 5,800 smolts could be provided by the new pond. This would increase drainage-wide coho smolt production by 60 to 90 percent. Additional overwintering use of the pond, by steelhead trout, is also expected.

Initial performance of the pond appears promising. During the first fall and winter of operation, two pairs of adult coho moved into the pond and spawned at the mouth of the diverted tributary. Additionally, preliminary data from smolts, leaving the pond in April, from an initial plant of 150 juveniles in late October, showed substantial overwinter growth. When introduced the coho juveniles averaged 75 mm in length and weighed about 5 grams. At departure, trapped smolts averaged about 135 mm in length and weighed more than 30 grams.

Project work in 1984 is to include: site surveying of one additional off-channel pond site and four potential side channel developments; development of one prototype side channel; addition of large woody debris for cover at selected berm sites; and installation of up to 30 whole tree alcove structures. The alcove structures will entail introduction of large conifers (root wad attached) into preselected channel areas. Generally, the sites have poor heavy equipment access. Introduction will be accomplished using special explosives and a blasting expert.

Annual progress reports, documenting Fish Creek project and evaluation work will be available from the Mount Hood National Forest or the Bonneville Power Administration. A report detailing 1983 efforts is currently available.

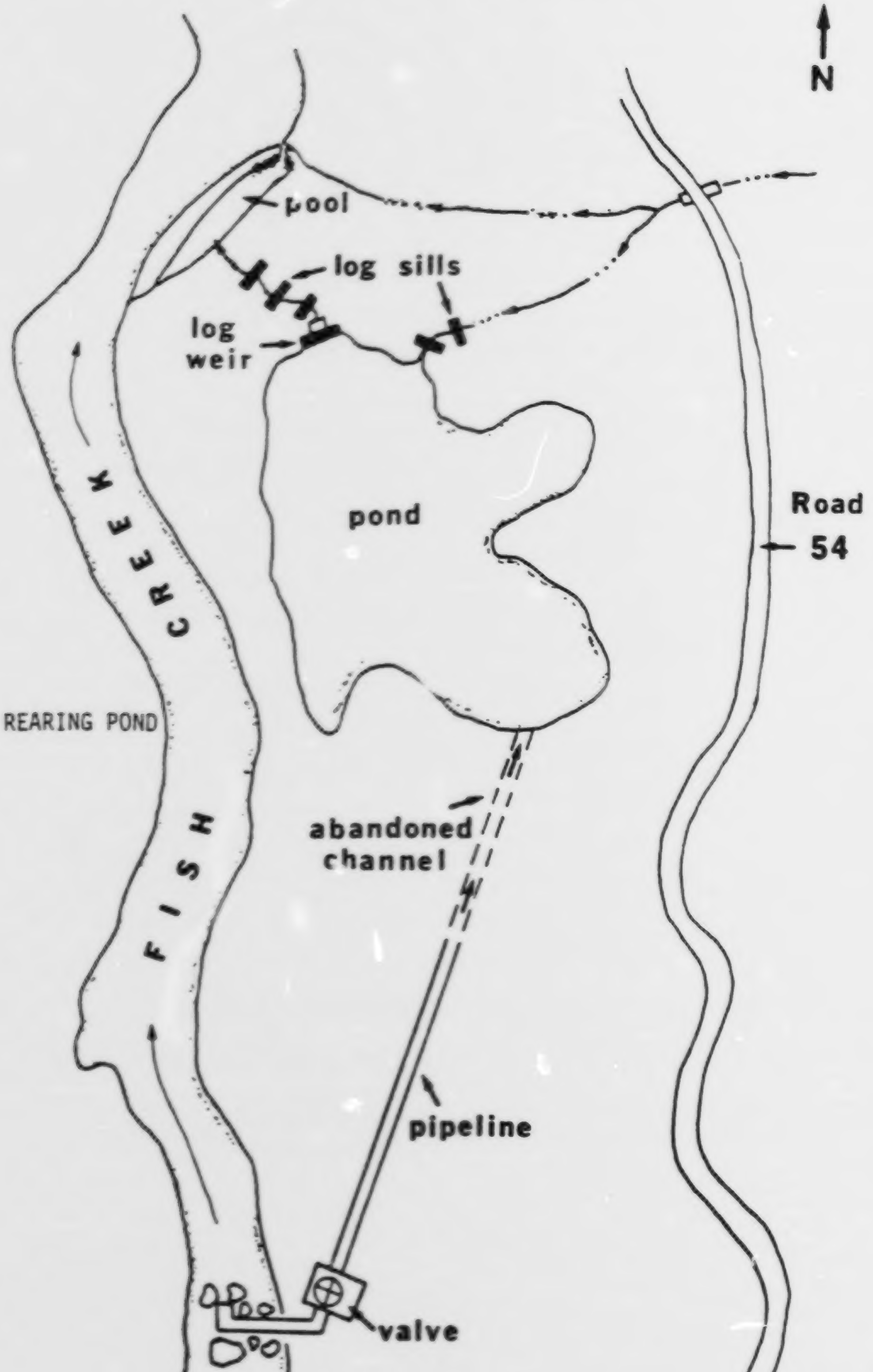
N
pool
log sills
log weir
pond
Road 54
FISH CREEK
abandoned channel
pipeline
valve

Figure 4.

OFF CHANNEL REARING POND

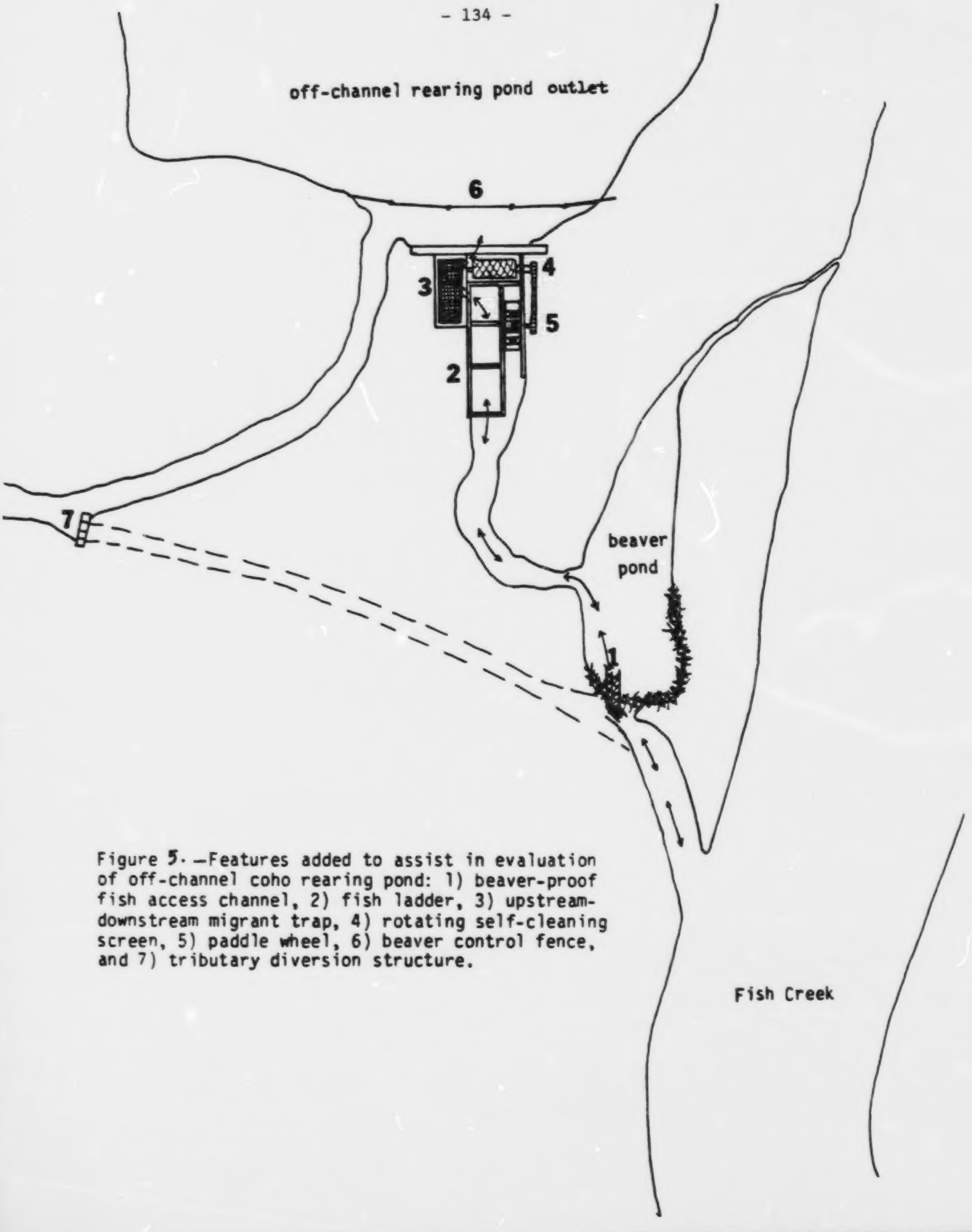
off-channel rearing pond outlet
6
4
3
5
2
7
beaver pond
1
Fish Creek

Figure 5.—Features added to assist in evaluation of off-channel coho rearing pond: 1) beaver-proof fish access channel, 2) fish ladder, 3) upstream-downstream migrant trap, 4) rotating self-cleaning screen, 5) paddle wheel, 6) beaver control fence, and 7) tributary diversion structure.

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QUESTIONS AND DISCUSSION
ON
ALL SESSION III PRESENTATIONS

(Brian Tutty, DFO, Nanaimo): A question to Brian Dane. Regarding your project, could you give the group some idea of what that 700 feet of enhancement work cost the proponent, and how those costs were shared?

(Brian Dane): It was actually the cost we got from the Department of Highways. They bore all the costs. As I understand it, the excavation work was around $10,000, for their contract costs, including the equipment.

There was an additional cost for transplanting which was more than it should have been. They went to an architect to do transplants, and of course, that means a lot of money. That ended up costing somewhere in the order of, I believe, $10,000 for transplanting and the cost of trees. It was rather expensive in that sense.

I haven't got a further breakdown of the costs, but they were all borne completely by the Department of Highways.

(Tutty): Roughly, then, $20,000?

(Dane): For that project, that's about what it cost.

(Al Lill, SEP, Vancouver): On that same question, what were the costs to DFO in terms of staff time and salaries?

(Dane): I think Rob (Elvidge, DFO technician) probably spent at least a week of his time off and on working with the operators; so I would say probably two weeks time.

(James Buell, Consulting Biologist): Dave Heller, I don't remember if you talked about the cost for the artificial beaver pond?

(Dave Heller, U.S. Forest Service): Yes, the total cost, with a number of contract changes, came in at $20,000.

(Buell): What was the smolt output you expected from the pond under full seeding?

(Heller): We're guessing 5,000 to 7,000 smolts annually.

(Voice): Dave Marshall, could you expand on the benefit/cost ratios for the side channels? What variables were included in the benefit/cost ratios; part of the national debt, and all the other things?

(Dave Marshall): The consulting firm of D.B. Lister & Associates, which does economic evaluations, came up with the benefit/cost standards. I think they based it on the SEP model, and I'm not an expert on it. The economists worked it out.

(Lill): The SEP benefit/cost ratios would bear no resemblance to some of the other benefit/cost ratios I've heard around today. The system that we use is very different, I suspect, from the kind of ratios that have been bandied about.

It's virtually impossible to get a benefit/cost ratio over four to one with our system, because the benefits to the producers, and the cost of fish harvesting, etc., is a cost, plus our cost, so you can see there's already a built-in ratio against you before you spend any dollars at all, presuming you have some fish. We use a 10 percent discount rate as well, which has a very big effect on benefit/cost ratios.

(Voice): When those benefit/cost ratios were done for the side channels, they included all the maintenance costs for the next 10 to 20 years, and also the statistical cost of the channels being damaged over the next five, 10, 15 and 25 years. They included the salaries of all the federal employees involved in them, and supervision of maintenance.

So, when you're talking benefit/cost ratios, just to back up what Al Lill said, you've got to be very careful.

(Lill): If it's over one to one it's pretty good.

(Buell): The way the National Marine Fisheries Service in the States has approached this, at least the philosophy that they have chosen, is to look at the value, not of the fish entering the fishery, but the value of a spawner returned to the spawning ground, and of the fish that spawner would produce, which would subsequently be harvested.

Just to put this into perspective, spawning spring chinook in the Columbia River system is presently valued at $550 a fish. This makes benefits pretty good if you can get them back. They have to run the gauntlet of a gillnet fishery, both legal and illegal, but still, it makes my life a little easier. This month there will be a review of the National Marine Fisheries Service evaluation program. Some of our b/c ratios are pretty high, some of yours sound like they're pretty low. The truth is probably someplace in between.

(Gordon Ennis, DFO, Vancouver): Brian Dane mentioned he was doing work in streams, and there were other people in habitat involved in a lot of small-scale restoration or improvement projects, usually as a result of development projects. I talked about some yesterday. Usually we're pretty happy if we can get these works done at all. I guess there's a trade-off between evaluation costs and costs of doing the work. Up to now, we've considered it a success to have any benefits accrue from these works, let alone evaluate them.

I see some research scientists who've spent an awful lot of effort on evaluation and don't do the day-to-day work, and I was wondering if I could get some input from some of the researchers. Do they have any comments on types of evaluations that could be done on these day-to-day habitat improvement projects; types of evaluations we could do with very little cost involved? We don't really have budgets for it, at least we haven't up to now. Or should we just forget evaluating these projects, and go by guess and by golly, which is more or less what we're doing now?

(Herbert Klassen, Consultant): I wonder if the habitat people at DFO Headquarters in Vancouver have looked at the possibility of establishing some sort of relationship with the people at UBC and SFU who are turning out students who might in fact give you a very good evaluation of certain kinds of projects. The projects might have to have certain characteristics to be useful for a bachelor student. If it was a larger project you might well get an MSc.

(Buell): I'd like to interject a personal note. I see a rather substantial difference in many cases between monitoring and research. The two can overlap a great deal, and there are opportunities for doing research-style monitoring, and I suppose monitoring-style research. In many cases, we're finding with some of the enhancement projects, especially under the Bonneville Power Administration program, that monitoring ought to be just that, if we're going to get any data back in time to make good administrative decisions with regard to going ahead with the program.

We may have amendments to the program, for another 3,000 log weirs in the next year or so, and B.P.A. is accountable to the ratepayers. There are going to be people asking some pretty tough questions. Decisions need to be made about the proportion of funds available to be spent on log weirs, where they ought to be put, under what circumstances; whether we ought to go for our best habitat and make it a little bit better, or worst habitat, and make it a little bit better. What's that going to do for fish?

The three-to-five-year research program isn't going to cut that. We're not going to be making those decisions. The program might be over, we won't be able to make the decisions that we need to make. On the other hand, there's a lot of valuable research opportunities.

So, monitoring, in my view, ought to be seen, at least many times, as being separate from research, but also done very carefully.

(Heller): Initially, we had a little bit of trouble selling our evaluation. We started with Forest Service money, and when B.P.A. came along we expanded it. But, our costs for the evaluation work alone are averaging about $45,000 a year.

We're actually spending more money on evaluation, at least in the first year, than we spent on doing work. It took a little bit of selling to get our managers to buy that. We're certainly not going to be doing that in a large number of areas, though. At least to the intensity that it's being done in Fish Creek, it's not inexpensive.

(Buell): In other cases, there have often been administrative requirements in the permitting process which require the proponent, or the developer, to pay the agency costs of the monitoring as part of the terms and conditions of their permit; or to contract it out, depending on special circumstances surrounding whatever activity it is.

If an agency feels that they're the only ones that can do a proper job of monitoring, then they might require certain compensation directly from the developer, or they might simply require that the developer choose someone else, subject to agency approval, to carry out the monitoring program.

(Tutty): A question for Dave Heller. You mentioned an interesting biostandard, which I haven't heard come up before. You mentioned that the pond created was 3,600 cubic meters, and you're producing roughly 4,000 coho smolts from it. That is roughly a smolt per cubic meter of beaver pond.

If you were to colonize fed fry into your kinds of habitats that are natural, would you put in five fry to get your one smolt per cubic meter? I'm looking for a stocking level.

(Heller): First of all, the 4,000 or 5,000 to 7,000 was an estimate. We haven't produced that. The State has done some outplanting of coho, but nobody's ever asked us what stocking rate we felt was appropriate. I think the one per cubic meter is probably high, and I think the only way we could justify that is where we have that kind of relatively warm, very rich environment.

Incidentally, each year, everyone that does one of these B.P.A. projects has to write a report and B.P.A. publishes them. That's a real source of ready information.

I have Fred Everest's report, and I can show you the densities by habitat type that we're looking at; that might give you a better idea.

(Tutty): I just wanted to maybe bridge the gap here. Rather than investing monies in creating the kind of habitats that you're speaking of, I know, in a lot of our watersheds, we have natural habitats that are empty like that. It would be very helpful if we had the kind of information that is flowing from your program to help us identify the targets and the densities.

(Heller): We have a lot of opportunity for that; however, we actually have two difficulties. One is reaching agreement with the State on that strategy and that may not be the major hurdle. In the Clackamas Basin, we don't have a hatchery source of the Clackamas river stock, stock which is a wild stock, to out-plant. In many cases, that's a concern, but I agree with you. I think that the only detraction would be that it would be an annual investment to put them out there. Presumably, if you built something like this, and it didn't require heavy maintenance, you wouldn't have that annual cost.

(Charles Scrivener, FRB, Nanaimo): We've got about 13 years worth of data from Carnation Creek. That might be of value to you for looking at stocking densities for upper uninhabited areas. We end up with very early populations that are declining rapidly, with a lot of surplus fry, until about July. The ranges that we've observed from July can be anywhere from about 30,000 to 15,000 fry over 3,100 meters of stream.

(Buell): I would say the pond that Dave Heller was talking about was incredibly rich. It had many feet of very black deposits in the bottom, and just full of bugs. It's not your typical side channel richness, so don't take those levels as being indicative of what the average cubic meter of stream could produce. But, there are probably those opportunities all around as well.

(Del Skeesick): I was really impressed with the standing crop estimates of smolt out-migration that Dave Marshall spoke of. Since that kind of habitat is a very stable habitat, compared to what's going on in the streams, I'm wondering whether what you really weren't seeing is part of the behavior of the juvenile coho. Perhaps, a number of them would be moving up into that as a protected winter habitat area, prior to their smoltification.

(Marshall): Some years ago, I looked at some stream carrying capacity data from all the various sources I could find. I think those first few slides I showed in my talk on the Cowichan River, showed smolt yields that would tend to exceed what you would expect to be normal rearing-carrying capacity of streams that size.

There are some fish rearing in those groundwater channels, others are migrating in the winter time, during the fall and winter freshets.

I did mention, near the end of my talk, that to date we had 4,000 smolts counted out of our Upper Paradise groundwater channel, the one that we developed. There's only 2,625 square meters of area so those high densities are kind of suspicous too. It might be good rearing, but that's almost unbelievable.

I think they're in there over winter and they're feeding on the chum alevins in the gravel. The gravel's quite porous, and I know coho can get right down in gravel, just like sculpins. The growth rate over the winter was quite phenomenal. At the end of the summer, they were only about two inches, and now I hear they're pan-sized.

So, it's coho enhancement by chum enhancement, you might say.

(Brent Lister, Biological Consultant): I have a question for Herb Klassen, regarding his gabions. Have you noticed any problems with respect to bank protection in the vicinity of the gabion structures, and do you have any idea what is a reasonable life expectation for the structures?

(Klassen): I did notice some problem with lateral bank scour. As water goes over gabions, it peels off perpendicular to the placement angle of the gabion, so it is being deflected towards the bank. I caught it very soon after one storm flow. There was some scour of the bank, but hand placed riprap up to .3 of a meter, or so, was enough to stop it. It's been halted.

The longevity of the gabions, I think, perhaps could be 10 or 20 years. I noticed that during a very major storm flow that the gabions didn't budge an inch, so it's hard to tell.

(Raymond Biette, Ontario, Ministry of Natural Resources): I agree with Gordon Hartman, the need to do surveys before we undertake rehabilitation work. Could you comment further on how this can be accomplished in a reasonable and economical fashion?

It's something that we've been trying to do in Ontario for the past ten years. We get one or two done, but it just takes so long before we get one completed. Then it's already out of date and things have changed before we actually go in and do the rehabilitation work.

Do you have any thoughts on methods of doing this, in terms of a short time frame? Secondly, what sort of dollars do you think should be spent on doing these initial surveys, and in particular, on a province-wide basis so you can priorize where you're doing to direct your rehabilitation work in the future.

(Gordon Hartman, FRB, Nanaimo): That's a hard question. When I was talking about coastal streams, the way you're going to have to do a lot of that survey work is to have people put on a set of boots and go up the stream. They're going to have to take certain measurements of conditions within the channel at fixed distances. They're going to have to record the volume, and the type of debris in these channels at fixed distances for a very large number of systems.

The idea I had, was, perhaps, we should be approaching this kind of survey work on the basis of generating more than the survey information. We could also generate some sort of a classification of the basins, in terms of soil and topography, and so on, so that after you did a certain number of surveys, you could at least begin to predict what you might expect to find in other basins, given they had had a certain kind of treatment.

I think that would be very difficult in B.C., because we have a range of different basin types, and a range of different types of logging treatment, and also a range of time since the treatments took place.

I think that the answer is that it's going to be expensive, you're going to have to get in there and get detailed information before you begin to get into it. There may not be a cheap easy way to do it.

(Biette): On a follow-up, do you think that rehabilitation projects then should slow down, in terms of what's being undertaken now, until that sort of work is done? Or do you think, that they should be going in some sort of parallel fashion?

(Hartman): I think we should be going in some sort of parallel fashion. There's been some work done in B.C., and I frankly don't know the total scope of it. The documents I've seen on stream assessment, haven't got into the kind of detail that I think you would need if you were going to get into restoration in areas that had been logged.

(Biette): What sort of dollars are spent now on the survey part?

(Gerry Taylor, MOE, Victoria): For very basic surveys, you can run anywhere from about 10 to 50 dollars a kilometer just for initial surveys, per year.

You want to make sure that you sample in a system more than one year, because you could catch it at any particular standing stock level that could give you a false impression relative to a diagnosis. We try to follow one year class through, particularly for coho, chinook, and obviously steelhead in any one system.

That means going back, usually at low and high water. The first year is habitat description and fish at low water, then in the second and third year it's looking at the fish populations.

It depends on the nature of a project. We've done habitat inventory relevant to the Coquihalla River Diversion, which is a million dollar diversion. We would expend $6,000 to $7,000 a year evaluating that, whereas some other projects where we're just looking at outplant, we might be spending $150 a kilometer the first year, and $50 the second.

(Buell): During Gerry Taylor's talk I heard reference to something that probably comes close to what we call a smolt capability index. It attempts to get an idea of the productive capacity of a system for smolts. Did I hear correctly that you have such a sytem that attempts to evaluate habitat, and comes up with the bottom line for production in terms of capability?

(Taylor): We're partway along that process. For steelhead, we're basically going with the 30 or 40 systems that we've looked at, and looking at mostly fry to smolt translation. The parr to smolt are difficult, except where you've got fence information and research that we can then apply as a biostandard to see what the likely translation rate is. We're not into that stage yet.

For coho and chinook that are sub-ones, we get some pretty good ideas, except we're not in the business of saturating with coho or chinook. We are with steelhead, so we have some models for some areas in the province that we can make some estimates on what smolt production is likely to be.

(Buell): What I was really getting at is the relationship between habitat and hypothetical smolt capacity, rather than actual output; for example, looking at a stream that, may not be currently accessible to coho. You want to evaluate the advisability of removing a barrier, and you want to come out with some sort of projection as to the potential for that habitat to produce "n" number of smolts.

(Taylor): Research is getting close. We've developed a steelhead smolt model, which we are applying on a coastwide basis, and we're going out and testing it. Obviously, that model isn't working well everywhere. Geographically, that model is probably going to work for east coast Vancouver Island type streams. It may not work for coastal streams, particularly given some of the kind of constraints that we've looked at in northern production, where factors other than what we have in that model now, are more important in the north than they are in the south.

We don't have something where we can say 3,000 smolts per mile of stream. We have those kind of estimates come out of some of the salmon literature. It's not too hard when you give me a stream that's 100 meters wide, and two feet deep, and it's occupied across its full length. That's a hell of a lot different than having the Skeena River, where it's only occupied maybe on 10 or 15 feet on either side as far as rearing is concerned. So there's some real problems.

(Hartman): In Carnation Creek, the number of smolts that we get out in the spring depends on the size of the fry that go into the winter. We get different numbers of smolts coming out, and what we get out depends first on the size of the critters that started out the winter. Probably, the second thing that may affect numbers is the relationship between off-channel production and main stem production which we expect may change from year to year, depending on whether there's a dry winter. If you have these fish using this off-channel habitat, then you get a dry winter. A lot of them will buy the nine of hearts out there. The next winter, if they go into that habitat, and things are wet, they do very well. So, I'm not sure that you can expect to come out with a simple bottom line. For a given system, you could look at a bottom line with confidence intervals on it.

(Scrivener): Essentially, we've got some nice little models to do that, but when you go into another system you haven't got the numbers to plug into the model.

(Lill): Dave Bustard, from your experience, can you suggest some prescriptions for improvement works that might follow in the Interior situation.

Obviously, lack of water in the side channels is a big factor, but if you were to go back next year with a contract to do some improvement works in those areas from an enhancement perspective, what would be the sort of things that you would look at as the best prospects?

(Dave Bustard): Part of that might depend on the scale you're talking about. Things like coho fry outplanting sound excellent for our Interior systems where we've got mazes of these pond areas associated with both main-stem areas and tributaries.

Certainly, we could so some manipulation of flows to increase the winter flows. Some physical changes, particularly along main-stem stretches of the river, where there isn't much in the way of habitat diversity, could perhaps result in some improvement situations. Some of those main-stem sites are probably very important for over wintering, and some things, like log placements, might be of considerable help.

Some of those things should be applied to areas where we do have groundwater inputs, whether it's for improving spawning or rearing.

(Rob Elvidge, DFO, New Westminster): Could you not use Dave Marshall's technique on side channels to alleviate some of your winter kill?

(Bustard): Certainly, in the channels that have inflows during the winter, I think it has really good possibilities.

(Hartman): Dave Marshall talked about the role of groundwater in the chum work that he did, which I think was really nice stuff, and Dave Bustard has talked about groundwater in the Kemano situation.

We see a lot of interesting significance, associated with groundwater, and the effects on intragravel temperatures, and hence, egg incubation regimes. One general thing that strikes me is that, in fisheries work, I think that we have to begin to drag in groundwater hydrologists to help us understand some of the things that are going on in the systems we deal with.

The second observation I'd make is that I get nervous when I hear discussions about the alteration of hydrological regimes. I don't want to start a fight with Dave Bustard, but in plucking the top off the peak of the flow of the Morice River, I'm not convinced you're not disrupting mechanisms there. That high peak flow process may in fact lay down some of your groundwater supplies that give you certain kinds of conditions much later on in the winter time.

Carnation Creek runs all summer, and it gets damn little rain. The water is coming from out of the ground. Gerry said we should be forward thinking and start accepting the idea of having regulation on flow. I don't know if that implied again taking off those high peak flows, but maybe it's that wet season, those high peak flows, in many kinds of terrain that put the water into the ground that feeds things like Dave Marshall's side channels. So, I think we really want to be careful when we're talking about doing things with hydrological regimes that may have some implication to the groundwater behavior.

(Buell): I'd like to underscore that in a couple of cases in Alaska, where the groundwater plays an important role in extremely cold systems. There was one tributary which had the fetching name of 570402, and was full of all kinds of anadromous fishes, and some resident rainbow trout. When the stream would freeze like a brick for most of its length, these fish were overwintering in places where there were deep scour pools. There was a fair amount of water running in the creek. It was all sub-surface, except where these deep pods intercepted the sub-surface flow, and where there was cover, particularly in the form of brush. The brush would protect the pools from deep ice formation, because they would shade them from the black body radiation of the night sky. That's only four degrees Kelvin up there, you know. It's pretty cold.

We also found that there were areas of groundwater inflow that could be identified in the form of seeps and springs, some of them under the surface of the normal flow. We could tell because at the sides of the stream no silt would settle there. You could see discolorations of the rocks, and we could measure water coming in. Those areas remained open, and they remained refuges from the cold for fish.

Beaver dams and beaver ponds, especially the deeper ones, are very important. We suspect strongly that at least coho, and most likely chinook, and maybe rainbow and dolly varden, get literally down inside the sticks, and twigs, and mud and stuff of the beaver dam and just bury themselves under there where water is still liquid. It's going to be cold, and they can peck away at whatever is growing, if anything, in the dam itself.

So, groundwater is really important, especially for streams with damn little of it in terms of surface water, either in the summer or in the winter time.

(Bustard): On one of the side channels we had, the flow was coming off the hillside. It was right in against the hill where the seepage was happening. The thing that really struck me is we had a road right up above the channel, and if that small seepage, for example, had been diverted another 300 meters down alongside the road, and then come out, we would have essentially lost a lot of the juvenile production in a fairly large side channel down below.

It really hit me that it was pretty critical to watch how we were intercepting some of these drainages from the roads, and how that actually might affect the larger channel during the winter time.

(Colin Levings, FRB, West Vancouver): What procedures are in place, say in the province here, for keeping track of what people are doing in the way of this type of work? I'm talking in regards to small-scale enhancement restoration.

(Taylor): A number of years ago, Bruce Shepherd started a system whereby he canvassed most of us that were involved in small stream work. We would lay out our projects, and that would be distributed among the various divisions of DFO and the Fish and Wildlife Branch. Not everyone subscribed to it. In fact, about a third of the people in SEP, and very few people in any of the other divisions, subscribed to it. That was one method by which we sort of kept a register of who was doing what. I think the SEP meetings last week in Victoria and again here today and yesterday, illustrate the fact that there's still a lot of individual, almost convergence, going on. When you look at some of the work that's being done, I see people looking across the room and saying, have you seen that, or have you heard about that, and you shrug your shoulders and say no.

I would suggest to you that maybe you have to come up with a method.

(Buell): The American Fisheries Society, Oregon Chapter, has a habitat committee, and I think it's the largest committee now. It's a very popular committee to be on. It's very active. Three years back, the committee decided to come up with a list of habitat improvement projects, just a list, with a few aspects on it, name and address and phone number of whoever was in charge of it. It was kind of like a "atta boy" to be on that list. Everybody wanted to be on the list. It's worked okay, it ought to be better, but it's a fairly aggressive idea.

If you were a local chapter of American Fisheries Society who wants to get involved, presumably both Provincial and Federal people are members, you could get your committee chairman to be aggressive and chase people down. Make sure that they get their project on the list, and distribute it to all the members. That's a method.

(Lill): I'd just like to point out that in the SEP annual report all the projects are listed. One difficulty is that the projects are organized geographically rather than by their nature. That makes it a little difficult for a worker who's interested in a certain type of technology or approach, to wade through all the other stuff and find it.

With SEP's first phase winding up now, with seven years of projects, we might get some kind of a final report for the whole program. Hopefully, we'd get them cross-referenced by type.

Tom Bird and I used to be involved on a habitat SEP kind of committee, to sort of keep each other informed on what was going on. We intend to get that going again. Hopefully, we will get at least the coordination between habitat people and SEP people who are working in the same field, and get that reactivated.

(Skeesick): Herb Klassen, when you gave your presentation on the use of gabions, you made the implication that this may be a tool useable in rehabilitating some areas that are affected pretty heavily by mass wasting from logging roads, etc.

In thinking about it a little bit today, I'm not so sure that that perhaps is as good an approach as you might think. We discovered quite a few years ago, as a consequence of the very large rains and snows in the Cascade areas of Oregon, that we had tremendous numbers of mass failures in the small to medium-sized streams. Those streams were capable of carrying that mass failure as bed load, until it got down into the stream bottom, into the major stream where the gradient dropped a little bit. When that happened, that large bedload began to settle out. All of a sudden, the stream just took off laterally and developed into huge exposed gravel floodplains. They've been a nuisance to us now for the last two decades.

We're just now seeing that stream begin to recover vegetation. Some of those large gravel areas are being revegetated naturally. I can see that gabions, if installed improperly, and installed with the concept of capturing a large quantity of bed load, could in fact cause a stream in an otherwise reasonably stable channel to burst its banks. Perhaps, it could even do more damage to your riparian area than if you had just taken your lumps for a few years, until that stream had a chance to carry that bed load on through.

(Klassen): I believe gabions do have a limited use. There are particular slope gradients where they would be most useful. I think they can stabilize a channel; where you have stable pools, a stable configuration. You would need to take precautions and riprap the banks laterally quite a bit to hold it within that channel, but I do think they can maintain stable channels in many situations.

(Skeesick): I'm sure that they will work in some circumstances, but I think we want to be careful and not consider them to be a panacea for capturing large quantities of bed load that are moving as a consequence of large mass failures.

(Buell): Mr. Marshall, in your side channels, did you ever install larger pools intermittently throughout the channel, either for holding adults, or perhaps even for subsequent to emergence rearing, for either coho or short-term for chum?

(Marshall): We haven't, but I think in future channel designs we might put in pools at the top. If you put them at the bottom they're just shooting galleries for predators after the chum fry that are coming through. We designed them originally just for chum, and we can see now that they've got some coho spinoffs. We could build all kinds of things in these groundwater areas; they don't have to be channels, they could be ponds.

(Buell): Boulder placement, perhaps, for some cover?

(Marshall): For cover, yes. We do have a pond started that's kind of an experiment. It's just south of here on the Cheakamus River. We don't think it has a favorable benefit/cost ratio because the amount of habitat that you create for the cost of excavating the material is not that great, unless somebody wants to come in and remove the gravel for building roads, as we did get last year, so we got it half dug.

(Buell): We found that in some similar channels on Fourth of July Creek, that a large pool in a funny shape at the head served as a collector for groundwater. It increased the groundwater inflow rather dramatically just at the head of the channel, and it was also used by fish. It wasn't built for fish, but they used it.

(Tutty): Mr. Marshall, since you seem to have a very effective technique, a model that is easily marketable now, where is the impediment in doing this in a big way?

(Marshall): More money for this sort of thing. I think we will be getting more money to do this sort of thing, I'm quite confident.

(Buell): When do you expect the heron rookery to become fully established next to your channel?

(Marshall): I got a tip that says you don't leave any tall trees or snags or branches for them to perch on.

SESSION IV—RIVER HABITAT IMPROVEMENTS

THOUGHTS AND OBSERVATIONS ON GRAVEL-BED RIVERS

Duncan Hay, P. Eng.
Hay and Company Consultants Inc.

The following points relate to geomorphic aspects of enhancement opportunities for spawning and rearing in gravel bed rivers.

PREDICTIONS

Analytical or empirical models are often employed to increase our understanding of physical or biological processes. Models are essentially input-output relationships in which the input parameters are independent variables and output parameters are dependent variables.

In stream morphology the independent and dependent variables are as follows:

Independent	Flow Rate	Sediment Rate	Sediment Size	
	Q_w	Q_s	d_s	
Dependent	Width W	Depth d	Roughness C	Slope S

POINTS

1. Slope may also be an independent variable.
2. To couple the variables into an input-output model we require four equations. These equations could be:
    a) Flow: e.g., $V = C \sqrt{RS}$
    b) Roughness: e.g., $C = 5.75 \frac{\log 12R}{a + \quad /7}$
    c) Sediment Transport: e.g. $Q_s = \frac{Xd}{SD} \left(\frac{\sqrt{gRS}}{V}\right)^n$
    d) Regime: e.g., $S = 0.068\, K^{-1} Q_B^{-0.45} b^{0.45} D_{65}^{1.22} D_{90}^{0.55}$
3. The confidence in the equation appears to be inversely proportional to its complexity.

4. The regime equation, or equations, are an attempt to solve the missing link in a closed form analytical formulation of geomorphic processes. There are numerous regime equations.

5. The results (output) of a geomorphic analysis may be affected by the regime equation employed. For example, for an increase in discharge the least energy regime equations would predict no increase in width, however, using Lacey regime equations would predict a percentage increase in width on one-half the percentage increase in discharge.

6. Regime equations are empirical and as such are most applicable and reliable for the streams from which the data was gathered, or with some possibility of error, streams which are similar in character to the data base streams. Regime equations derived for sand-bed rivers should obviously not be used for gravel-bed rivers.

7. If serious about understanding or enhancing a particular system them a data base should be generated to develop regime relationships.

8. Fixing a variable, for example width or depth, eliminates the need for one equation and increases the confidence in predicting the outcome. For example in the design of artificial channels Q_s is zero. By fixing the river bed it is easier to calculate and predict changes in velocity. In a mobile bed a reduction in width may, or may not, increase the velocity of flow.

OPPORTUNITIES FOR ENHANCEMENT

Most "undesirable" features in natural systems relative to spawning and rearing are related to independent variables. The discharge, Q_w, fluctuates too rapidly or widely; the sediment transport, Q_s, is too large resulting in lateral instability, or there are too many fines, d_s, because of sidewall instabilities, etc.

The best opportunities for enhancement are most likely where natural or man-made controls exist on the independent variables because the outcome of enhancement efforts can most readily be predicted (low risk).

Opportunities exist:

1. For Controlled Discharges

    a) outlets of lakes
    b) ground water springs
    c) downstream of some dams
    d) stream diversions
    e) utlization of older channels in wide valleys

Low storage systems subject to rain or snow events should be avoided.

2. For Controlled sediment movement (Stability)

    a) stable valley walls
    b) upstream of high Q_s tributaries
    c) downstream of rock canyons
    d) downstream of rock outcrops which control planform geometry

    Poorly incised channels, deltaic area and debris-jam prone areas should be avoided.

3. For Controlled Sediment Size

    a) glacial-alluvial geologic history

    Avoid streams supplied by lacustrine sediment sources for spawning enhancement.

4. For Controlled Slope

    a) incised steep gradient channels offer good opportunities for slope control
    b) utilize bed rock outcrops

    Avoid reaches where the water surface slope is controlled by independent downstream water levels.

CLOSURE

Geomorphic features should be included in any inventory of enhancement/restoration opportunities. The inventory should identify hydrologic and/or geomorphic features which may create an opportunity for various sites.

Not every reach in every river or stream, in fact, not every stream, offers attractive opportunities for fisheries enhancement. Enhancement and restoration involves management. Some rivers and streams are more easily managed than others because their behaviour is more readily predictable.

Opportunity for enhancement rests to a large degree with our ability to utilize and/or minimize the conditions when nature provides the most productive environment.

MAJOR RIVER DIVERSIONS—SOUTH EAST COAL BLOCK—BRITISH COLUMBIA

J. A. Wood, P. Eng.
Kerr Wood Leidal and Associates Ltd.
D.B. Lister
D.B. Lister & Associates Ltd.

SYNOPSIS

The southeast coal block is located in the southeast corner of the Province of British Columbia very close to the Alberta border. The area includes five operating coal mines as well as other coal properties in the planning stages. The past and ongoing development of these mines has and will necessitate the diversion of major creeks and rivers.

The Fording River Coal Mine near Elkford, B.C. was put into operation in 1971 and in 1977 approximately 1100 metres of the Fording River was diverted to provide space on the valley floor for the expansion of the tailings disposal facilities. Although other diversions in the southeast coal block are discussed the primary topic of this paper is the diversion of the Fording River (Figure 1).

The Fording River diversion was constructed with a 20 meter wide bottom and included nine drop structures 750 mm high. Each drop structure consisted of two steps with a plunge pool in between. The drop structures were formed from selected rocks with relatively rectangular dimensions. The rocks were typically 1.20 metres deep and 2.4 metres long and were excavated into the bottom of the channel.

In between the drop structures large rock islands were placed. These rocks were selected for their shape and in particular the undercut faces. In time, scour pools formed around some of these islands to create resting areas and rearing habitat. The following items should be noted concerning the first seven years of operation:

1. Deep scour pools formed below the second step of each structure and created ideal habitat for the resident trout.

2. The scour pools formed in soft shales and silt stones and were relatively stable after the first five years of operation.

3. Scour pools formed around approximately one third of the rock islands which provided seasonal pool habitat at moderate flows.

4. Some of the rock islands were integrated into gravel bars that resulted from deposition created by the meander sequence that formed in the channel after one year of operation.

After two years of operation, Fording Coal Limited implemented a monitoring program to assess the fish utilization of the diversion relative to unaltered sections of the Fording River.

FISH UTILIZATION

The Upper Fording River supports only one fish species, a population of Yellowstone cutthroat trout (Salmo clarki lewisi). The population is slow-growing; a four year old fish averages 22 cm long. To compare trout densities in the diversion with those in unaltered sections of the Fording River, fish population sampling was conducted at four representative sites in the diversion and at the same number of sites upstream (above mine) and downstream (below mine) of the diversion.

Relative to the two unaltered river sections, the diversion supported the highest average trout density in numbers and an intermediate density in terms of biomass (Figure 2). Mean weight of trout was lower in the diversion than either of the unaltered sections. The large size of trout in the above mine section reflects the relatively high abundance of older (age 4+ and 5+) fish, probably due to the absence of any significant angling pressure in that section.

Within the diversion, trout made greatly different use of areas at drop structures, i.e. immediately downstream, and areas in the 75 m sections between drop structures. In July, virtually all trout were located at drop structures, while in September the numbers at and between drop structures were about equal (Figure 3). By November, most trout in the diversion had returned to the vicinity of the drop structures, presumably for overwintering.

Trout densities at the drop structures substantially exceeded densities between drop structures, i.e. 49 times greater in July and 2.6 times greater in September. The abundance of large rock and the plunge pool below each drop structure created especially favourable conditions at high discharge in early summer and in the late fall-winter period. The sections between drop structures, which contained few boulders and pools to provide holding areas for trout at high discharge, were only utilized substantially as discharge and stream velocities declined in late summer.

Figure 1. Fording Coal property and aquatic study area site plan.

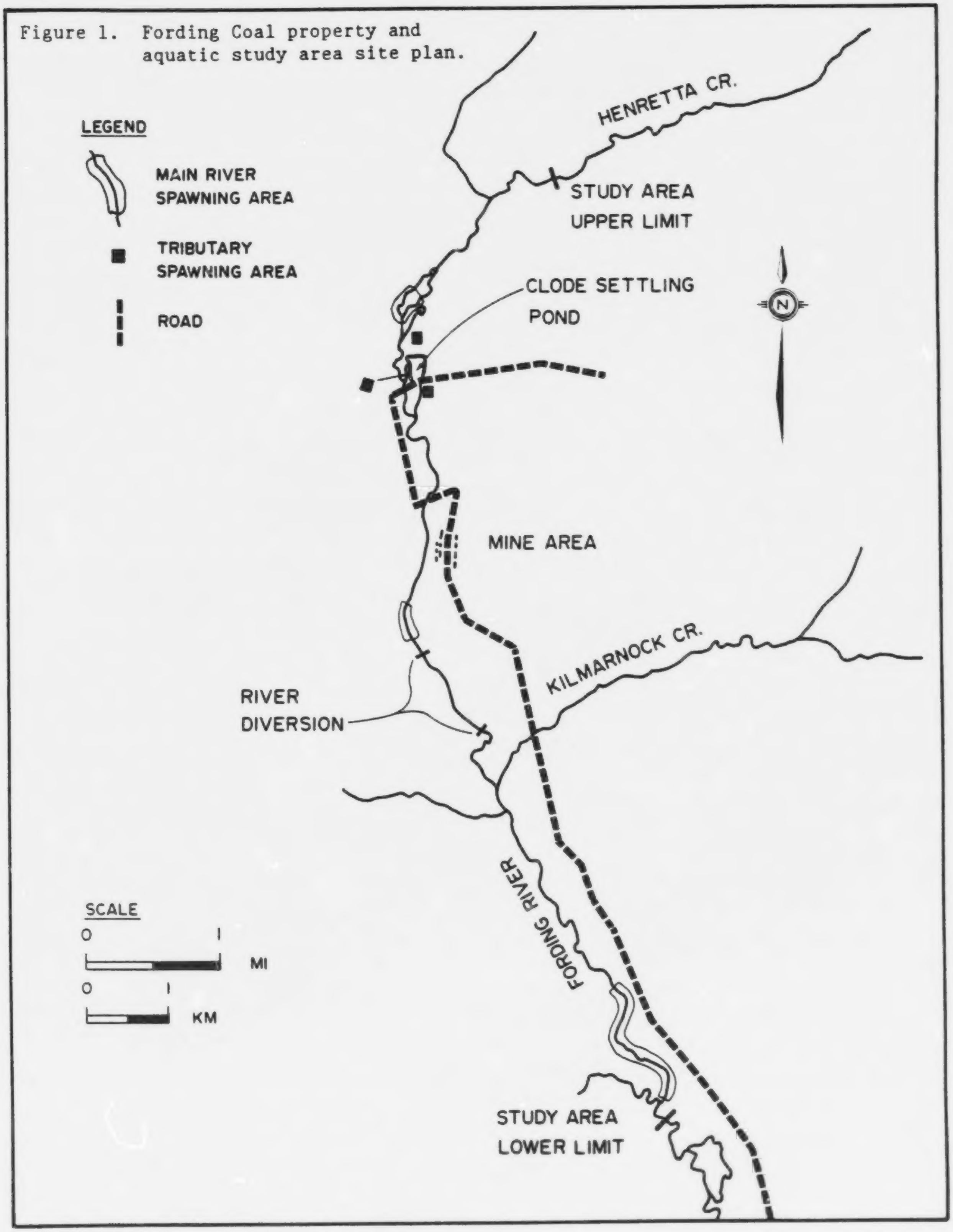

LEGEND
MAIN RIVER SPAWNING AREA
TRIBUTARY SPAWNING AREA
ROAD
HENRETTA CR.
STUDY AREA UPPER LIMIT
CLODE SETTLING POND
N
MINE AREA
KILMARNOCK CR.
RIVER DIVERSION
FORDING RIVER
SCALE
0
1
MI
0
1
KM
STUDY AREA LOWER LIMIT

Figure 2. Comparative densities and mean weight of cutthroat trout in the Diversion and unaltered sections of the Fording River upstream (above mine) and downstream (below mine) of the Diversion.

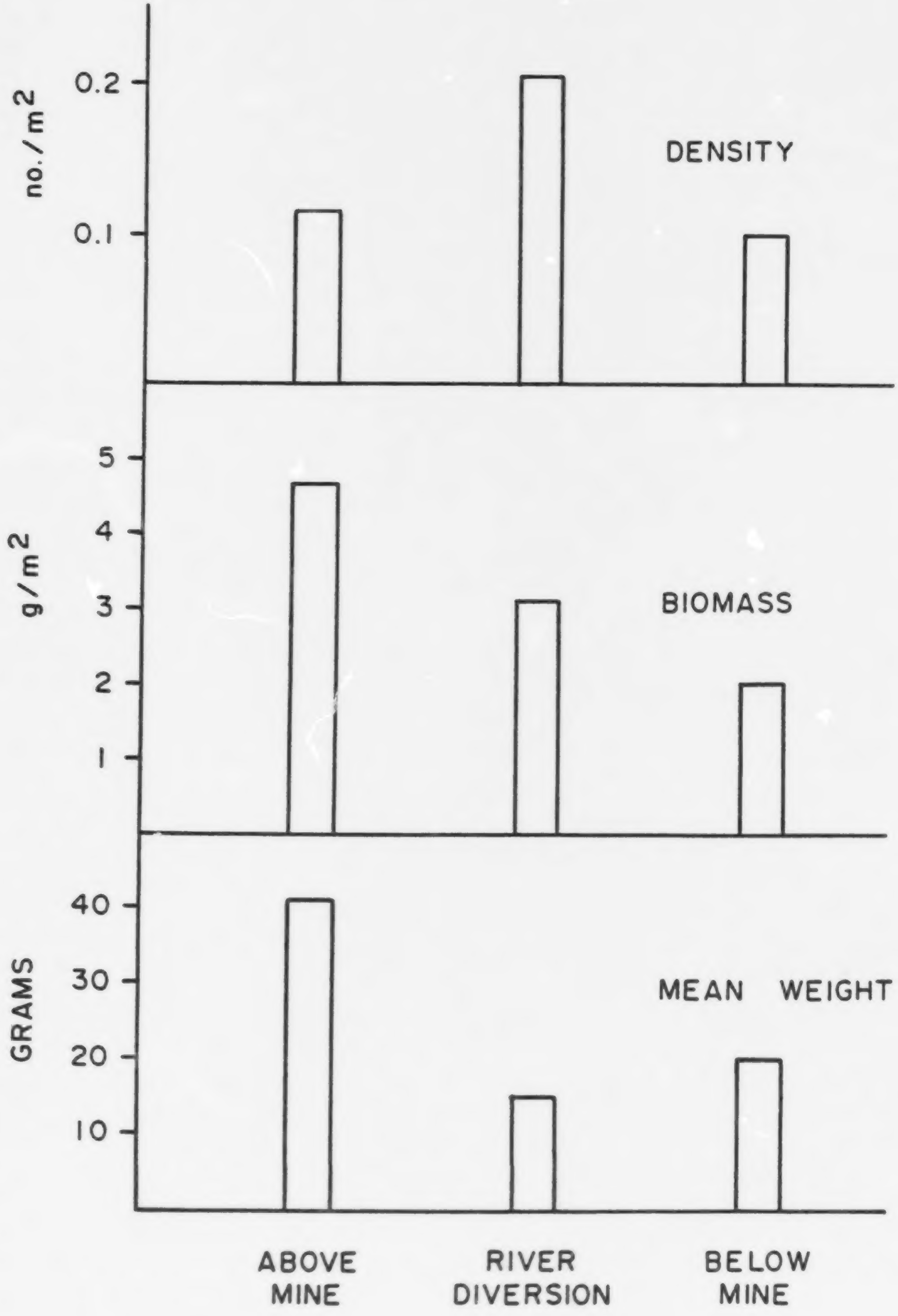
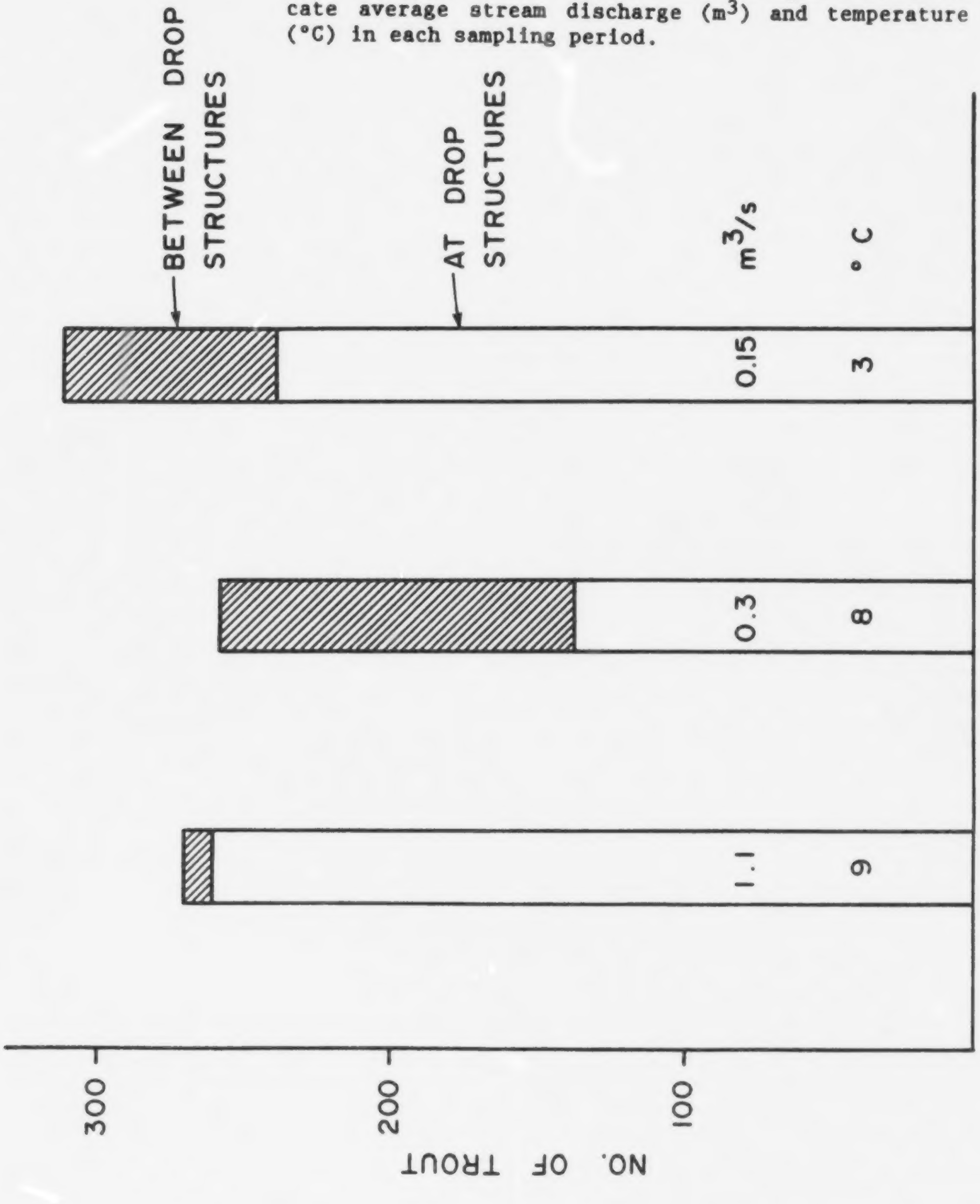


Figure 3. Seasonal differences in distribution of cutthroat trout within the Fording River Diversion, as indicated by densities at sampling sites immediately downstream of drop structures and at sites between drop structures. Numbers in the open bars indicate average stream discharge (m^3) and temperature (°C) in each sampling period.



STREAM ENHANCEMENT IN THE OREGON COAST RANGE

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ABSTRACT

Tobe Creek, Oregon was studied in 1982 and 1983 to compare physical and biological differences between a young alder stream section logged and cleaned of large debris 20 years ago and a mature mixed conifer section unlogged and containing large amounts of large woody debris. Stream enhancement techniques were used in 1982 to simulate large woody deris in the logged alder section to try to increase salmonid use. Large woody debris in the channel caused the development of secondary channels, meanders, pools, and undercut banks in the unlogged, mature conifers stream section. These elements were noticeably missing in the young alder section. The mature conifer section had more than twice as many pools and 10 times the amount of spawning gravel. Salmonid biomass was significantly greater in the mature conifer than the younger alder section prior to stream enhancement. After enhancement, no significant difference in salmonid biomass was found between stream sections. Prior to enhancement, three times as many coho salmon (Oncorhynchus kisutch) and trout fry were living in the mature conifer stream section. Also, there was a positive correlation between coho salmon numbers and the presence of large woody debris. Results of the study revealed, that structure, most likely, is a more important factor than shade in governing a stream's capability of producing salmonids.

WASHINGTON STATE HABITAT ENHANCEMENT PROGRAM

Larry Cowan and Dave King
Fisheries Biologists
Washington Department of Fisheries

In Washington State, our salmon runs are subjected to a barrage of harvest pressures, often times, resulting in below normal spawning escapements. Our habitat enhancement efforts are geared to maximize the survival success of those fish which do return, thus helping to balance out some of the harvest pressures. In this report, we will be presenting the different types of enhancement projects that we are involved in which improve salmon spawning and rearing habitat.

We are conducting a wide variety of projects and quite a large salmon enhancement program. We're currently, and for the last three years, have been involved in a labour-intensive program which has a dual purpose. Number one, is salmon habitat enhancement, but in addition to that, it's aimed at being a labour-intensive program to put unemployed fishermen and loggers to work because of the recent recession.

We have been involved in the spring channel concept for the last three years, ever since we made a trip to Canada and saw the success that Dave Marshall had. Kelsey Slough is a 600-foot channel on the east fork of the Satsop River, a tributary to Grays Harbor, which had good quality spring water, however, a muck bottom. The muck bottom was excavated and clean spawning gravel was placed in this channel which has several fingers. It is also important for overwintering and summer rearing for coho salmon. We installed artificial undercut banks to provide cover for adults and rearing juvenile salmon. Dave King is currently doing evaluation work on three of these spring channels.

One of the features incorporated in Kelsey Slough, is a raising of the water level to increase rearing area during the summer months. The water level is then again lowered in the fall and winter for optimum spawning and incubation conditions. Another type of spring channel that we built is downstream a short distance. We protected an old side channel with a dike, excavated the channel out below the dike, and installed a culvert to augment the flows. Once excavated, the channel had excellent flows. We placed log controls at nine-inch steps. The channel receives an average of 500 adult chum salmon spawners every year. It has also proven to be an important coho rearing and overwintering area. The log controls worked very well for step structures. Again, on this particular channel, artificial, undercut banks were installed. One of the important features of these undercut banks is allowing hiding areas for the adult chum. We've had poaching problems; dogs have been observed in the channel, dragging salmon out. The undercut banks give the salmon a place to evade predators.

A 1,500-foot channel (Fortson Creek) was developed on the Stillaguamish system for pink and chum salmon. We didn't want to disturb the vegetation along the banks so we limited our access to two points and bladed the muck bottom to various take-out points and used a clam shovel to excavate the material out and place new gravel into the channel. In addition to the channel, there was one section--a side channel--for eyed-egg plants to stimulate the pink and chum runs in this system. Debris was placed back into the channel to provide cover for rearing salmon. A number of thumbs were dug off the main channel to maintain an irregular channel morphology.

Two old mill ponds, which form the headwaters of the Fortson Creek channel, have a 500-foot section of stream between them which is utilized by coho and is excellent rearing area. At this site, there was a logjam which blocked coho. We removed the logjam and constructed a fish ladder. It was a labour-intensive effort; concrete slab poured and the steel I-beams placed, bolted in and stop-logs placed to create a five-step fishway. It is very effective in passing coho.

A coho overwintering pond was another project done on an experimental basis last summer on the Clearwater system. A one-acre pond was built. This is a continuation of the work that Jeff Cederholm and Phil Peterson have been doing in evaluating the coho utilization of overwintering areas in the Clearwater system. In this system, because of the high winter flows, a large portion of the coho production will seek out these spring-fed ponds during the first freshets in the fall. They will remain there through the winter and emerge as smolts in the spring. This pond was built with the idea of maximizing the rearing area and minimizing predation opportunities. The banks were not planted with anything that might act as a perch for birds. It was evaluated pre-project and is currently being evaluated to see what type of production we might get out of it. In the upstream spring water source, there were log controls placed and several gravel spawning areas built. Adult coho were transported in last fall and spawned successfully.

The middle fork of the Quilceda Creek is a very excellent coho producer; however, this is an area that had been ditched along the road and it's an area of gravel deposition. It is the site of a channel change project done last summer. Previously, it was necessary to dredge out the channel at least once a year and when that happened the habitat was disturbed along with whatever fish were rearing there. It's a 1,300-foot long channel and when we made the change, we shocked out 3,000 coho and cutthroat.

The landowner for this channel donated a 40-foot easement. We placed a straight channel, with a high flow sill designed to take flood flows. We were not able to meander it because of the limited width of the right-of-way. However, this summer we'll be placing woody debris and log controls and some boulders to provide a more optimum rearing habit. This was heavily spawned with coho last fall.

Upstream of the channel change project, we constructed a gravel sump, designed to catch the gravel at this point. We have an agreement with the county that they will maintain the gravel sump here, rather than dredging along the load.

Fish passage is the most cost-effective type of project that we are involved with and consequently the most abundant. Logjam removal is the most direct form of fish passage. Another part of the program is involved in establishing fish passage over rock cascades. For example, we worked on an old fish ladder that was built during the early 1950s. In the upper part of the channel, it was passable for coho and chinook, but not passable for chum. The problem was that the major flow in the fall would come over the falls, decoying most of the fish into a deep pool area just below the falls. It was a good site for poaching and our escapements are not high enough that we can afford to have our chinook and coho poached at the level they were being poached here. We widened and reduced the gradient in the fish ladder channel, which now passes chum. Charges were set; over 300 cubic yards of material were removed by hand. A bypass flume will be added that will discharge at the mouth of the fishway to take the majority of the water and provide a strong attraction flow. In addition, deep pools were constructed at the falls. The falls portion of the project was done first and fish were easily moving over it as we were doing the rest of the project. This was a $15,000 project.

We have also constructed a $5,000 rock fishway in the Toutle system which was heavily impacted by the eruption of Mt. St. Helens. We are involved in selective habitat restoration work in that area.

Culvert passage is another important problem that is inhibiting fish from utilizing vast areas of excellent habitat. We are currently involved in fixing the more cost-effective culverts, and in most cases, at least a portion of the bill will go to the culvert owner.

In some of our older projects, gabions have been used to step up the streambed, providing passage through the culvert. We no longer use gabions in an exposed situation because large organic debris catch on the exposed portions of the gabions and rip the tops out. High flows will blow out the contents of the gabion, leading to continual repair problems. In addition, the gabion will rust, especially in streams, where during summer low flows, the gabion is exposed to air. We've had to replace the tops of gabions that are six-years-old because of this problem. In the early 1970s, we installed about 40 major gabion stabilization type projects so we have had some experience with them. As a rule of thumb, we use gabions in areas where they are under the gravel and never exposed; they work great and they will never wear out. We have gone, instead, to log controls; they are more aesthetically pleasing, never hang debris up, and if you have to change the elevation on a control because of the movement of gravel in the streambed, or just poor design or poor installation of your design, it is a matter of just using a chainsaw to notch the logs out.

A small wooden fishway is an inexpensive solution to about a four-foot drop out of a culvert on the Nooksack system; it passes fish, but is a high maintenance type of a fishway and has a short life.

Fencing is another project that we are involved with; recovering the riparian zone along areas heavily impacted by cattle. We revegetate with a low brush species: snowberry, vine maple, wild rose, and dogwood. The grasses come back quickly. The cuttings we put in are rooted stock, usually 18 to 20 inches. Debris placement is used to provide habitat, and in this particular case, bank protection, to protect a side channel. Upstream from this particular project, we cabled in a large quantity of debris to keep the river from breaking through into the upper end of the project. The project was in the middle fork Nemah, a tributary to Willapa Bay.

Our labour-intensive crews have been involved with moving large debris out of the stream, and in some cases, moving debris in. Our famous "Gravel Gertie", is a machine that was developed experimentally to clean spawning gravel. It does that very effectively; the cost of cleaning is about $2.00 per square yard. We have used it in areas where we have suitable gravel and can dig a spring channel and then just take the machine and clean the gravel rather than replacing it. Currently, we are using the machine one month each summer to maintain our spring channels and clean up point source sediment contamination. In the fall, we have wild brood stock trapping operations. We utilize egg incubation boxes to reseed habitat that we have rehabilitated or habitat which has recovered and is underutilized. Another form of habitat recolonization that we use is the eyed-egg plant. We incubate the eggs to the eyed-stage and then bury them in the gravel. Evaluation of this method indicates that if clean eggs are used we have over 90 percent egg-to-fry survival in a spring channel situation where you don't have scouring flows.

We are involved to a limited extent in a rearing program to rear coho up to the one gram size for outplants into areas where the habitat is inaccessible above dams or into areas where coho escapements are low. We have fibreglass rearing units that are portable and rear 150,000 coho to one gram.

Finally, we are involved in limited public education as advisors for egg-box installations and small community stream rehabilitation projects.

I am going to expand on one aspect of the program and that's side-channel renovation. Schafer Park Slough, an old side channel of the east fork Satsop River, received flows only during high water and was subject to dewatering at normal flows. Chum salmon would be drawn into the channel and would spawn during the freshets. Most of the production was lost from the dewatering effect. Our idea was to excavate it down to groundwater level and then build a protective dike at the upper end. In the dike, we installed a flow control valve that is situated in a culvert and can be closed down completely. There is a sufficient amount of perk water entering the channel without having the culvert open. Directly below the culvert, we felt a spot for silt to settle out was needed in case we had some problems with that. A five-foot deep pool was excavated which provides good rearing for coho and other species. Log controls were installed throughout the channel to prevent gravel shift during high flows and to step the gradient down evenly.

Pools, two to four feet deep, have formed below each log control with little or no bank erosion at the end of the logs. Artificial undercut banks were created with the use of logs placed parallel to the stream and four feet from the bank. The logs were elevated above the streambed with one-foot diameter wooden spacers and then wire mesh was placed to span the gap between the bank and the log. Excelsior matting and vegetation was placed on the wire and tied down with cable to prevent washing off during high flows. This dense matting should provide a good medium for new vegetation to gain a foothold. The whole log system was anchored to the streambed with rebar to prevent floating downstream.

In Kelsey Slough, the contaminated streambed material was removed and replaced with clean spawning gravel. This channel was identified as an important rearing area. At the lower end, a wooden dam with stop-logs was installed to give us the ability to raise and lower the water level upstream to flood more area for rearing. During the fall, the stop-logs are removed to allow the chum easy access to spawn. After the fry have gone in the spring, the stop-logs are reinstalled. An accessory bypass channel is available to allow fry to move in or out of the channel freely.

This is one of our artificial undercut banks covered with leaves and brush. We did have a problem with beavers. They took all the brush off one of the cover logs and used it to build a dam downstream.

Simpson Slough was identified as a potential project when water was observed in the old side channel at extreme high flows. The channel was brushed out and excavated to a depth of five feet in certain spots to obtain a water depth of at least eight inches. All of the spoils were placed into a protective dike between the main river and the channel. The water was very silty during construction but cleared up rapidly. Excellent percolation in the channel helped clean out any silt that had settled on the gravel. Approximately 52 adult chum spawned in the fall which helped clean it even further. During high water, water backs up into the channel from the main river to a depth of three feet.

This spring, we started our evaluation and installed traps in three channels. Egg-to-fry survivals ranged from 38 percent to 77 percent. Additional years of evaluation will be done to get a more complete picture of survival rates.

QUESTIONS AND DISCUSSION
ON
ALL SESSION IV PRESENTATIONS

(Jim Buell, Consulting Biologist): Duncan Hay, I'm fairly certain that the thrust of control that you were talking about was not absolute control. At any rate, as a fish biologist, trying not to be an engineer, I wrote down a few items.

A certain amount of instability is necessary for all biological systems, because biological systems are active processes and require other exogenous active processes for support. Salmonids living in hydrological systems need those systems to have a certain range of instability.

For example, spawning gravel must be scoured in order to maintain a certain permeability and active meanders, scour, and point bar formations are important ingredients. Much of the gabion, log weir, and woody debris work that is being done is intended to bring the stream into an optimum range, if you will, of instability.

Discharge instabilities are also necessary within the range that is appropriate to a certain stream. Vertical and lateral instabilities are also vital, the former in an ungraded stream, especially, and the latter, in a graded stream.

It isn't a desire to eliminate risk in our work, but only to reduce it to an acceptable, or perhaps an optimum level. We learn much more from our mistakes than we do from our successes, because our mistakes are more embarrassing, and we pay more attention to them.

In graded streams, debris jams are very important features. They promote habitat variability by promoting channel instabilities and promoting the stream to get out of its banks and form new channels. This produces a greater variety of habitat, which is capable of supporting a greater variety of fish and life stages and life processes, and so forth.

That's the end of my philosophy, if you have some reaction?

(Duncan Hay): One reaction is that in school I can recall a professor saying that an engineer's reputation is built on his mistakes, and yes, we learn from mistakes.

One of my points was that we can also learn from other people's mistakes, and we don't have to reinvent the wheel.

Relative to stability, I've heard basically two things at this workshop. There is one school of thought, perhaps of your colleagues, who are looking towards more stable environments. Then, you're saying instability is really something you want; maybe that's a question of degree, and you're going to have to quantify that if that's quantifiable.

How much stability is desirable? There is such a thing as dynamic stability which takes place both in coastal geomorphology and in river geomorphology. There are erosion processes going on, but you basically have stability. A meandering river is basically a dynamically stable structure. The process is slow enough that you can probably have adaptation in the biological sense.

That's only an observation. The same is true insofar as the profile. Scour downstream of a gabion is dynamic stability. You'll always have it, there will be scour, it will vary, it will go up and down. You have scour during a freshet, the bed doesn't stay the same.

The system basically remains and keeps the same shape, and maybe that's really what you're after.

(Brian Harris, MOE, Penticton): Mr. House, a number of times in your talk you mentioned that you keyed in the gabions. Do you mean that you actually buried them in the bed of the stream, or did you key them into some particular feature of the stream?

(Bob House, BLM, Oregon): Before we put the gabions in, we levelled out the streambed; we removed the armouring, the cobble, the rubble, and the boulders, and we used those to fill the gabions. We set the gabions on the streambed after it was levelled, and then we keyed them into the bank, sometimes up to six to eight feet deep in that bank. We tried to look for different objects in that bank such as a rock outcrop, or an old log or something that we could key the gabion into, to add stability to that gabion.

For three years, we had no bank erosion at all, on our gabions on East Fort. On three other streams, we've had two years with no problems at all with the instability of the gabions, and the banks.

(Errol Claire, ODFW, Oregon): To Duncan Hay and Brent Lister, I got a little bit squirmy when I looked at a moonscape for a stream, and these types of channel changes. Over the years, we've had a tendency to try to stay away from that type of thing.

One of the items that I didn't see, either upstream or downstream, or within the channel that was created, and about which I didn't hear anything mentioned, is whether you did anything, or whether there were any plans for any riparian redevelopment, or riparian restoration.

(Alex Wood): First of all, that moonscape picture you saw was right in the mine. Everything's flat, and for an outsider coming into the mine, that's what he's got to deal with. They are in the process of stripping it for the mine, and that diversion is right in the middle of the mine, or towards one end of it, so there was no flexibility.

The Alco mining, the last picture I showed you, beautiful. We have a situation there where we can save all the vegetation. Some of those side channels would be four to five feet coming into the main stem from the overwintering areas, all overhung with native willow.

Fording (Coal Mine) have tried to get willow started, but not, I'd say, with a great deal of enthusiasm. They like to put the grass down and make everything green. Mines are really good at making everything green, even the telephone poles, the equipment; they spray everything with seed and fertilize it.

At the lower end, they did start to handplant some of the native shrubs, actually a form of willow that only grows at that 6,000-foot evevation. They started that, but they didn't finish that program. They were supposed to plant the whole diversion.

These are pretty stable pools because they're in a form of rock, a sedimentary rock there. There's where they should have concentrated some of their planting, because it was unique. You go up a few feet from the bottom of that channel into soil again.

It just happened that the invert ended up in rock, and the banks are in a gravelly soil.

(Herb Klassen, Consulting Biologist): To Bob House, what was your range of stream gradients in which you installed your gabions? Did they have any noticeable effect from the steeper to the shallower gradients?

(House): Probably about the steepest gradient we worked in was about three percent. We figure that as the gradient gets steeper you put your gabions closer together, and that's generally what we try to do.

The rule of thumb that we used, and John Anderson used, is that the top of the downstream gabions should hit midway on the upstream gabions. That roughly gives you your proper gradient spacing when you do that.

(Art Tautz, MOE, Vancouver): To Duncan Hay, I've been sort of impressed with just how much problem there has been in applying what seem to be good engineering models, or good engineering theory, to these kind of situations.

It strikes me that somehow the information base that's out there isn't really being used effectively in a lot of the designs of these instream methods, and also in just describing habitat for fish.

Do you feel that the equations can be a theory that applies to a lot of these practical type problems?

(Hay): The knowledge that's available hasn't been applied in some instances.

Insofar as river geomorphology is concerned, we've been trying to develop the predictive models, probably for a longer period of time than you, as biologists, have been trying to develop predictive models. We can still back off and say, yes, we don't have enough data to make the prediction in certain instances. I think that's true. But, our data base for the regime theory, I think, is wider than your data base for biological models. We've been at it longer.

What I was trying to do was draw a parallel between where we've come in river morphology, in developing models to understand the system, with where you're going to have to go in biology, and where you are going. That's one of the things I was trying to do.

I was also trying to make an apology, although I don't think it's necessary, for the engineering community. In certain instances, when asked to give a definitive answer, we can't give it. Why we can't give it is because sometimes we're dealing with an equation that's very empirical, we don't have the data base to calibrate that equation.

The other point I'm making is it's stacked. There are certain things, certain phenomena that we understand very well, and we could predict very well. I think that there's also a parallel in your activities, certain models you have which are very predictive and very well calibrated. When you throw them into a larger system and introduce more variables, you need to have more equations and more models to tie them all together.

(Wood): Some of those formulae and equations only apply to very homogenous situations. They may be for the sediments in the Delta of India, which is very fine and very uniform, and if you use some of the formulas there, you can come up with some pretty fair answers. But don't try to apply them in the streams in North Vancouver that are 25 percent grade, or in other circumstances. You've got to be very careful how you apply those. If you ask an engineer a question to do with a specific stream, he may hesitate before he answers it, because he might not have the right parameters.

Some of the hydraulic formulae don't hold when you get up into higher velocities. They're very inaccurate, for example, critical flow.

The formulae that we rely on so heavily for open channels work, like in spawning channels and low gradients of one and two percent, are pretty accurate. They've been measured many hundreds of times.

In some cases, you have to do model studies, like on a confluence of a diversion where it's joining a main stream. You can have some funny things go on there that's not calculable. You'll actually have to do a model study to predict what's going to happen at the outlet.

I think that's a safe statement, is it?

(Hay): Yes, a physical model is just really an extension of a mathematical model, that's all. Another form of a model.

(Buell): Perhaps, we can talk about river habitat improvements in the context of a little bit larger stream than some of the projects we've seen earlier. The point was made earlier that some of the types of techniques that we've been experiencing with wood, and gabions, etc., are not necessarily too applicable to the big streams. A fair amount of our production in British Columbia does occur from medium-sized larger streams. I'd like to have Alex Wood and any others comment on that area.

(Wood): In the lower Elk, you're into very high flows. We made a proposal to divert it, match up the meander sequence, establish one or two pools which are historically already there. We were using the same shape, etc., but we concentrated on the peripheral items, such as some good side channels. We stayed out of the main stem because there was nothing we could do in it that was going to be stable. So we worked, we made our proposals in side channels that we weren't wiping out by the diversions.

There was some excellent habitat for rearing, beaver swamps that were tributary to the big river. I guess you could say we ignored the river for enhancement; the main stream, it was going to take care of itself. But, we did spend a fair bit of time emphasizing what you could do in the neighbouring side channels, and the neighbouring beaver swamps that drained into the newly relocated stream.

(House): I'd like to add something to that. Carey Overton has shown in northern California that you can go into huge systems and rework them and have stable structures. He's had dramatic results in big flashy systems, using large boulders, just as you were using, and they've remained stable. And they've been subjected to some horrendous flows the last two or three years.

(Wood): The big pools I was referring to are stable. That's about all we would put in some of these big rivers. Very few people have seen a 100 or a 200-year flood, and it's scary.

(Al Lill, SEP, DFO Vancouver): Earlier, Dave Marshall mentioned side channel work on the Paradise, which is just south of here. There is an excellent little cutoff stream called Tenderfoot Creek, which is just on the other side of the Cheakamus River in which we have done some enhancement work.

(Colin Levings, FRB, West Vancouver): Dave King, do you have any plans for marking the fish for long-term survivorship data in the evaluation work?

(Dave King): We don't have any plans right now to mark fish. We're just developing our evaluation program.

(Levings): Do you think that you'll eventually go that way in order to compare hatchery with wild stock production?

(King): It's possible, but we're in the very early stages, so I can't really say.

(Bob House, BLM, Oregon): You mentioned that you were pulling woody debris out of your streams. Are you still doing that, and to what degree?

(King): Yes, where it's causing problems, where the stream is completely plugged with woody debris, where passage is restricted. We're not cleaning the stream completely out, we're leaving enough debris to provide plenty of cover. It's a program that was originally set up and called stream cleaning, but as it turned out, that was a bad name for it; we quickly corrected that.

(James Buell, Consulting Biologist): Have you evaluated for artificial undercut banks? They look great, but have you gone in and electrofished and seen what the coho are doing under there?

(King): No, we haven't. As I say, we're just starting our evaluation.

(Buell): Do you have coastal cutthroat in those systems?

(King): Yes, we did catch some cutthroat in our fry traps, but very few.

(Buell): You might look for those under those logs. It looks like real great cutthroat habitat.

(Dave Marshall, SEP, Vancouver): Since you started building those groundwater channels three years ago, how many have you built, how big are they, and what did they cost?

(King): Schafer Park Slough was started three years ago; that cost $34,000, and we have roughly 2,200 square yards. Kelsey Slough, which was the one with the stop-log, was $17,000, and we have roughly 1,000 square yards there. The final one, where we didn't replace the gravel at all, was $6,600 and we've got roughly 550 square yards.

We can build the channels, where we replaced the gravel, for around $15.00 a square yard. The one, without replacing the gravel, was $12.00 a square yard. The thing that's adding to the cost now is we're starting to put these labour-intensive crews to work putting in vegetation. That adds up in a hurry.

(Art Tautz, MOE, Vancouver): You mentioned that you were stocking coho fry above barriers. What sort of rates are you stocking, and what's the procedure used to select your sites?

(King): Our Harvest Management Section sets up the stocking rates and picks the locations for us; we just go out and plant the fish.

(Larry Cowan): For the Puget Sound area, the general rule of thumb that's used is .42 fry per square yard of available rearing habitat, that is, if you want to put fish into a stream and you don't know anything else about it.

We are involved in very extensive stock assessment work. Our key coho-producing streams are being evaluated for both spawning escapement and downstream migrant fish. In any of these streams, we know exactly what the production capabilities are. For instance, a stream in the Stillaguamish system would be stocked at a rate that is appropriate to that stream. We would choose one that would be similar to one that we've evaluated and use that stocking rate.

On the coast, the stocking rates are much more general. We're currently involved in doing some stock assessment work on the Chehalis system, because it seems to have some production problems.

For other coastal streams, the rule of thumb is 5,000 coho per mile on a small stream, and 10,000 coho per mile on a large one. There's limited evaluation on the coastal streams, with the exception of, say the Clearwater, where there's extensive work being done. As has been brought out throughout this workshop, it's a system by system approach. Each system has certain characteristics. The coho density for outplanting would be different for different systems.

(Brian Tutty, DFO, Nanaimo): We've had quite a number of discussions about using gabions in streams. Yet, you are using keyed logs as an alternative because of rushing, impalement, catchability for large organics. Would you care to expand on that? I was given the impression by the various presentations that gabions were an effective tool, and I'm wondering whether your experience would suggest otherwise?

(Cowan): We've done a large number of gravel stabilization projects, and we have experienced a high maintenance factor for them. For example, if you have a system where there's large organic debris moving, you get that debris snagging on an exposed gabion surface, opening it up. Then, if you have ensuing high flows, it will scour out the cobble that's in the gabion, thus requiring maintenance.

The other problem is the scouring downstream of a gabion. Because it's not a rigid structure that spans the entire streambed, you get scouring, and it will tend to sag over time. This is our experience.

I realize not everyone has had this experience. Over time, what we've found is that if you have heavy scouring right at the base of the gabion, it will tend to sag. Eventually, if the scouring is severe enough, it will roll over. Consequently, when we do put gabions in, we'll build a large mat, we'll have an apron below the substrate. It would be two gabions wide at the bottom, in a pyramid shape, and then the top gabion is just one two-foot-wide gabion. This will prevent the scouring, if the gabion downstream of that is placed in such a way that you don't have excessive drop.

At the conclusion of any project, we always have to put in a streambed level control, because no matter where you end, you've got a drop over a gabion, or a log, or something. If it's a foot drop when you get done with the project, the next year when you come back, it will be two feet, because of the scouring effect. The streambed is removed down below, and you end up with a fish block.

We've had to come back in and repair a number of our projects where we didn't protect the stepping effect by having the streambed level controlled at the end of the project.

(Voice): You showed in one of your photographs, an over-wintering pond for coho. Do you have any criteria that you apply in those types of situations?

(Cowan): That pond was one that was built under the supervision of Phil Peterson, as a continuation of his work that he's been doing on Clearwater. The shape is designed to optimize circulation through the pond. It's kind of a horseshoe shape with a berm in the middle of it.

The fact that there was no vegetation planted--ordinarily we would plant those banks--was to limit roosting places for predators, and also to maximize visual contact between predators. Evidently, birds if they can see another bird across the way, will be inhibited in utilizing the area.

(Buell): Did you ever think of placing large debris in the bottom of that over-wintering pond in the form of large waterlogged root masses, or whatnot?

(Cowan): That wasn't done. They definitely want to evaluate what it is about these ponds that makes them so productive, and limit the variables.

SESSION V—WATERSHED IMPROVEMENTS

Introduction by:
Gary Logan, Head
Small Projects Unit
Salmonid Enhancement Program, DFO

I had the pleasure of being on a tour of Washington, Oregon, and Northern California in January (1984) and saw some of the projects with which they were involved. I think they can teach us quite a bit about riparian habitat and instream structures, particularly on the small scale.

One thing that I noticed in the States, and that is they attempt to develop watershed plans. This is one area that I think we've really let ourselves down in British Columbia and the Pacific Northwest in that we do not have watershed plans. It is hopeless to have individual groups, whether they be provincial agencies, private industry, or federal agencies going into watersheds and enhancing things on an individual haphazard basis, without target species in mind, and target fisheries related to that.

We've had a lot of discussion here in the last couple of days on small technology. My fear is that the giant pendulum from where we are right now, which has been a heavy complement of hatchery production, is going to swing too far the other way, and we're going to have nothing but small technology. I'd be the first one to say that hatcheries have their place in this program. There's no way that we could have met the fish poundage figure required from us in the five account system for the federal/provincial Salmonid Enhancement Program (SEP) without our production facilities.

We have to identify more strategic locations for these facilities so that we minimize our stock interaction problems and target on terminal fisheries, thus minimizing the impacts on our wild stocks.

I'm a firm believer in the inventory process; however, my fear, again, is that we might go into it too deep. I've heard discussion here in the last couple of days about the extent of inventories; I think we have to come up with a common system that isn't a study-intensive type of inventory.

We have serious problems here now. Our small streams are big producers for our sport fish. We have to get our act together and start working with these problems now. Otherwise, in five years we may not have to answer these problems, because the fish aren't going to be there.

In some of these small streams we're working with remnant stocks, and by that, I mean 25 pairs of fish and under. Given our bio-standards you can quickly run through the calculations and determine how many years it's going to take to get any kind of escapement back to that system with the fishery as we know it now.

Research, obviously, has got its place. I think research has to be production orientated, operationally orientated. It has to address the problems that we are having in the field, and help to eliminate our stock problems.

Coordinated resource management, cooperative resource management, whatever you like to call it, has to happen. There is no way that we can continually fire fight as we are right now. We have to have watershed plans, we have to anticipate where we're going to have interaction, whether it be with forestry, mining, agriculture, recreation, whatever. We are joint users of the resource, and we have to recognize that now. We have to be prepared with management scenarios when we go to the table to discuss integrated resource management.

My last point deals with two immediate stock problems. As a biologist, I recognize the paucity of data available in some instances, to make management decisions. We have strong data in some areas for some improvement techniques; other areas there's weakness. For watershed studies, we have specific data, we don't, in some cases, have watershed overviews. We have to address now the problem of genetic integrity. We are worried about fish colonization, satelliting programs, and transplants. That's fine, these are all buzzwords, but it's a problem now. Unless we take the initiative and take the information we have now and go forward with that, as best we can, we'll be lost.

The second issue is species interaction problems. We all realize the worth of the cutthroat program, the value of coho and chinook, and their contribution to tourism in British Columbia. We have to categorize our streams, indicating our prime areas for individual species production. We cannot afford to minimize production of these various species in different areas. We have to maximize everything we're going to do, or we'll continue to lose fish stocks and overall production. And it has to be done now.

RIPARIAN REHABILITATION AND HABITAT MONITORING

Errol Claire
District Fish Biologist
Oregon Department of Fish and Wildlife
John Day, Oregon

I'm going to give an overview today on riparian rehabilitation. This subject is very broad based and to be able to cover it in 30 minutes would probably not do it justice. I am going to give you an overview of some of the things that have been going on in Oregon, particularly in central, east central and northeast Oregon, and present some case studies, and talk about some of the impacts and some of the benefits to the fish resources.

The John Day Basin is somewhat unique in the fact that it supports the largest remaining wild, naturally-produced fish runs of salmon and steelhead left in central and northeastern Oregon. The river supports populations of spring chinook salmon running from one to four thousand fish, and the 16-year average for steelhead is about 13,500 fish, with runs in some years of over 30,000 fish.

Our Commission has adopted wild fish management strategies and our goals set in 1975 called for the management of wild stocks in that basin. With this in mind, we recognized that we were going to have to look pretty close at what some of the habitat problems were.

In 1964 - 65, we sustained a 100 year flood in the river basin. This flood resulted in significant loss of riparian and instream habitats. To prevent future flood damage, the Corps of Engineers, one of our friendly federal counterparts, came in and put 31 bulldozers in a thirty-mile stretch of river and absolutely gutted the river, consequently wiping out a major trout fishery. We had heavy channelization after the flood and, of course, the ranchers went with that philosophy because the Engineers told them that was the right way to go, so they started putting their bulldozers in the river. They proceeded to do this year after year, until the early 1970s.

Between 1967 and 1971 we banded together with various local entities, including the Soil and Water Conservation Districts, the Soil Conservation Service, our department, the Forest Service and anyone who had some interest in land management or stream management. We came together to try and put together a program that was superior to using a bulldozer in the river. I had advocated for many years that you can't manage streams with a bulldozer.

This cooperative effort started and some of the early things we did were probably not the best, but we field-tested a lot of techniques, generated some ideas, learned from our mistakes, and started to find things that would actually work for restoring riparian systems and stabilizing stream banks.

In 1971, we got another shot in the arm when the people of the State of Oregon recognized that channelization was not in the best interest of the State and we passed the Oregon Fill-Removal Law or the Oregon Waterway Law which requires permits for the removal, fill or alteration of any State waterway supporting game fish. It didn't say that the stream had to support anadromous fish--salmon or steelhead--it said game fish. It did not specify numbers, so technically I guess you could assume if a stream had one game fish you could interpret that we had regulation under this new law.

Regulation is no better than the people and the enforcement that you give it; consequently, the area biologists and the technical people were in the driver's seat as far as the enforcement and administration of this law. It gave us a hammer. Frankly, I've crawled on a few Cats over the years, sometimes at the consternation of a landowner. Gradually, we began to get channelization shut down in favour of techniques that were more permanent or semi-permanent for resolving the problem.

In 1973, we formed a Coordinated Resource Plan in concert with the Forest Service, Bureau of Land Management and Soil Conservation Service, for the south fork of the John Day River system which encompasses about 103,000 acres in that drainage. This generated about $250,000 for instream and riparian habitat improvement over about 38 miles of stream. We also brought in a project with the Soil Conservation Service, under their emergency flood control program. It was modified and closely controlled so that in addition to streambank stabilization we also got some fish habitat benefits out of it.

The 1980 Northwest Power Planning Act just recently passed and has given us another shot in the arm. There is now a plan put together for the John Day system that totals $20.2 million of Bonneville Power money to move ahead a program of riparian and instream habitat development over the next few years. To date, we have spent about $1.2 million on riparian and instream habitat activities.

I just can't emphasize enough the value of cooperative effort. Together we stand, alone we're fragmented and probably doomed to failure, so I really want to emphasize interagency and landowner cooperation in these programs.

Just recently, our department submitted a five-year plan to BPA for restoring riparian and instream habitat on 80 miles of stream on private lands. We feel that this is very important. There is significant habitat in private ownership and it's an area where we are going to have to bite the bullet and work on that habitat. It tends to be a little more complicated when dealing with landowners, but we think there are opportunities based on some pilot projects we've had going with landowners.

I think we can offer the landowners some things tied in with our programs where fish and wildlife will be the beneficiaries of good management and the landowners will also benefit. I don't think we need to go out and sell them on fish and wildlife; that's somewhat immaterial to them, but we can sell them on some of the benefits that they'll derive from these programs. This five-year plan will total about $1.4 million.

This gives you a brief look at where we have been and where we are going.

I'm going to present an overview and talk about central and northeastern Oregon. I am located at the upper end of the John Day Basin in Grant County. We are 270 miles upstream from the Columbia River. The John Day Dam near the mouth of the Columbia River is about river mile 114. There are four major forks of the river; the South Fork, about 55 miles long; the main stem, about 275 miles long; the Middle Fork, 65 miles long and the North Fork, 106 miles long. It is the third largest basin in Oregon, covering 8,010 square miles and encompassing parts of eight counties, four national forests and 12 different forest ranger districts. There are 4,350 tributaries totalling 9,300 miles of stream. There are no major dams and no major barriers. We have a few minor, small irrigation diversions. The basin lies in what we call our northeast region.

We need to understand the different types of uses that are occurring that either relate to, or have some kind of an impact on, the riparian systems. We have recreation that is a non-impacter. We have livestock grazing which is a big factor to us because it is a number one industry in eastern Oregon, and we have timber.

Studies have shown that these riparian zones are the single most important key areas for the production of various species, in terms of numbers and diversity of wildlife. They are used, in some cases, year round and in others, seasonally. Roads have a big impact; that is a big concern to us. Of course, these zones are water producers; we're learning more things about the value of these systems as reservoir areas and the bank storage capacity to release water later on in the summer.

We've had a lot of mining. A lot of the gold reserves taken in the State of Oregon came out of the John Day Basin, so mining historically and to some degree, today, has been a problem.

In 1981, the Oregon Legislative Assembly declared that it was in the best interest of the State to maintain, preserve, conserve and rehabilitate riparian land. This is another significant first. They passed Oregon's riparian tax incentive program, Senate Bill 397, and it was the first in the nation where the State officially recognized the value of these lands. This became effective in January of 1982.

We are just getting started in this program, but we see it as a big step in terms of the State recognizing the value of these riparian lands. The area that we will be looking at is the riparian area from the water's edge back through primarily, the hardwood vegetation zone. This tax program does not involve the upland zone.

We will be talking about the riparian zone and how we can stabilize stream banks and restore vegetation that provides the shade, provides the bank storage and helps improve water quality for fish and aquatic resources.

We need to have some knowledge and be able to understand what a degraded system is. The morphology in a degraded situation has no overhanging banks; has no emerging bank vegetation; generally, the stream banks are crumbling and eroding; every high flow is a factor; a lot of erosion. In a recovery state, some of the emergent vegetation, some of the pioneer species come back in, the streams narrow and deepen, going from a horizontal profile to a vertical profile. We are looking for a narrow deep channel, good bank vegetation, and good undercut banks to provide the kind of habitat we need. Probably 20 years ago, and I can draw from my own experiences, we didn't recognize what was going on. We probably saw the cattle down there switching their tails and the dust was flying and the Kentucky bluegrass was a quarter of an inch long, but we really didn't realize what was happening. Today, we do know some about these riparian areas.

Another thing, that almost caused trouble in the early years of the program, was the perception that we were after 80 percent shade on every mile of stream. You have to know what your site potential is. This is a high meadow situation, which is very typical of some of our country. You want to set goals to restore good overhanging banks. A stream that is full of trout is a good situation. There are a few hardwoods, but it is not a site where you are going to produce a significant number of hardwoods, so you have to know what your site characteristic and site potential is. You need to understand what your goal is and what those banks are capable of producing. An example, which I class as an ideal situation; there is instream structure, pool habitat, good water quality, a lot of woody material and expectations for 80 to 100 percent shade and cover.

Generally, we find that in our key steelhead streams, we have the potential for possibly 80, and in some cases, up to 100 percent shade. You are not looking for 100 percent on every inch of every stream because you do need sunlight to maintain production. The balance that you will need to get the desired recovery depends on the type of restoration work you do.

In high desert country with 10 to 16 inches of rainfall, the riparian band is very fragile and very narrow. Basically, the agricultural industry has cleared the lands from wall to wall and the only riparian opportunity that you have is primarily that band along the river.

On many of our key summer steelhead streams, the upland is rimrock, sagebrush, wheatgrass, and pretty much a dryland situation. Along the stream, you are looking at very narrow, fragile bands of vegetation. It doesn't take a lot of activity to eliminate this vegetative corridor from the streams. Once that happens, there are stream flow problems, sediment problems, bank breakdown, stream temperature problems and everything else that goes along with it.

The South Fork of the John Day River is a medium-size stream, with up to 1,000 second/feet of water on an extreme freshet. Flows normally run, however, from 50 to 300 second/feet of water. These streams are very productive and if temperatures are maintained and kept cool and the water quality is maintained, they are tremendous fish producers.

We have to put some of the problems in perspective. I think when they developed the chainsaw and bulldozer, we took a very steep slide down the primrose path to destruction. The kind of thing that was going on was to go in, snag and clear, gut it and wipe it out, clean it from point A to point B just to get the water through. We are trying to get this type of thing shut down.

We had plenty of channel changing going on. A hardrock channel change on a good steelhead tributary of the John Day River was drilled, shot, straightened out and consequently 5,000 feet of stream were wiped out. We did some mitigation, but how do you grow vegetation out of solid rock. We had some running battles over the years to try to get this kind of thing turned around.

The gold dredge turned us upside down. They tried to tell us that as they went through there, the fish came right up and fed behind the dredges. Actually, all they were really doing was gasping behind the dredges. Miles and miles of beautiful steelhead and chinook habitat was lost to gold dredgings.

In 1971, Oregon passed its Forest Practices Act with stream protection as part of the program. At the first meeting, I was to present a slide show. Unfortunately, it never happened as it was impossible to deal with the problems in that negative environment. We did start dealing with this kind of thing one on one and turned some of the logging operators around.

Grazing, mining and mismanagement on these streams resulted in tons and tons of soil and silt cementing the spawning grounds and wiping out the sport fisheries for months on end. This also resulted in significant bank breakdown.

Streambank erosion is one area of common ground you have with the landowner. The landowner can understand when an alfalfa field or a good meadow is going down the river. This is where we have some common ground to talk about how do we restore and resolve this kind of a problem.

Sixty percent of our spring chinook on the upper, middle fork spawn in one particular section of the river. There is no vegetation here. The burn piles are what is left of the riparian habitat. This is private land and the rancher took a bulldozer in and cleared it. Fifty-three percent of our land base in Grant County is in federal ownership, but a lot of the major riparian lands and the good gradient streams are within private lands. After the land was cleared, the cattle were put on for five or six months, thus eliminating any future riparian vegetation growth.

We needed to know a bit more about where some of the sediments were coming from. People were arguing that it was from upland sources. A study on the Warm Springs watershed which was actually a reservoir study, showed that 50 percent of the sediment was coming out of the streambank areas, 10 percent was gulley erosion and 35 percent was sheet and rill erosion. This tells us that most of it was waterborne erosion and that the soil is going to be down in the stream. Five percent was miscellaneous; it probably went to wind erosion. With this in mind, we realized that we could do some significant things if we could restore those stream banks.

But what is the impact on fisheries?

In Utah, on Big Creek, there was degraded stream habitat, silted spawning grounds, broken banks and poor cover. It produced about 130 fish per mile. In a restoration situation putting in some structure, getting the integrity of the banks rebuilt, they were able to bounce that back up to 470 fish per mile. In this case, these were resident trout but we found that the anadromous fish response was the same because all salmonids had similar habitat requirements.

Idaho did some studies on channelization and the resultant loss of riparian systems and they found that the ratio was eight to one. They had produced eight pounds of fish in an undisturbed channel to one pound of fish produced in a disturbed channel and its loss was of long-term duration.

One of our studies made some comparisons on a small tributary to the middle fork of the John Day. We looked at steelhead populations and forage species. We had 60 to 80 percent cover in some areas, zero in others. Lack of cover resulted in high-forage fish densities and low rainbow densities. Good shade resulted in high rainbow densities and low-forage fish densities. There was a definite interaction that was primarily related to water temperature. Our study paralleled some of the other studies that have been done in the western states.

With rainbow and cutthroat, on a small stream, comparing percent increase in trout production for areas of controlled or light livestock grazing to heavily degraded areas, the average was 185 percent increase in trout production for lightly grazed areas. That is significant.

Where you have no stream cover, particularly in high-desert arid situations, there will be significant water temperature extremes.

Day-night fluctuations have some really important aspects in terms of fish production. The difference in the temperature peaks between day and night is extreme where no stream canopy exists. There is some very dramatic relationships between temperature and riparian cover on a stream.

I emphasize a cooperative effort in solving riparian problems. We have a very close working relationship with the Forest Service, Bureau of Land Management and Soil Conservation Service. Within the framework of policies and administrative rules, we are working together on these types of programs to restore these fragile habitats.

We used a grassroots approach. From a field manager's perspective, we spent time in the field looking at what the problem was, looking at what produced fish, what didn't produce fish. We tried to duplicate the natural sites that produce fish. We laid the plans out on the ground and looked at some of the basics.

Stream fencing is an important tool, not the only tool, but one to have in your arsenal of techniques. You are going to have to have fencing in certain places to resolve, particularly, livestock problems. As an example, on the main John Day River, on the old dikes we have controlled livestock use. This is what I call river containment. We're not in the business of river containment. I don't think any of us want all of our streams looking like rocklined canals. We no longer allow these gravel dikes to be built.

On Camp Creek, tributary to the Middle Fork John Day River, a small enclosure was built back in 1964. It was heavily scoured, beat out and there were only two clumps of alder. Today, under livestock control, we have about an 80 percent canopy. Another 14 miles of stream was fenced; this has changed the stream quite dramatically. The fish populations have averaged about 125 percent greater upstream than in the control area downstream, where little stream cover exists.

There is a definite physiological relationship between ice conditions in the winter time where there is riparian and where there isn't. We found that the ice will go off nearly 30 days earlier on these small streams where there is good riparian canopy. The ice is also about half as thick and the temperatures were anywhere from two to four degrees warmer in this upper section stream where the canopy existed.

The water table can be raised by creating fish habitat with various types of structures.

We should use streambank rehabilitation techniques as tools to stabilize banks only long enough to get the riparian habitat to recover; for example, on the Main John Day River, we armoured the bank with juniper and did some streamside fencing. Today, the alder, willow and riparian vegetation are about 25 feet high. We did not ever have to do more structural work on that bank. On the South Fork, we are using the juniper technique on a 15-foot high cutbank and today, it is completely masked out with vegetation and the stream is narrowing down.

In concert with our riparian programs, we're trying to improve the instream habitat in those areas where the riparian is in a recovery mode. We have been very successful and are strong on these types of programs.

In cases where the bank would undercut and it was on the outside of a turn, and too severe to use juniper as a vegetative stabilization technique, we used rock deflectors to collect the sediment, in combination with some seeding and replanting to stabilize the bank.

Beaver can be beneficial; they release a lot of hardwood cuttings and material that will sprout. Beaver actually provide a function in the development of riparian systems; raise water tables, increase summer streamflow and were vital historically in maintaining riparian systems. Beaver should be managed to assure their vital role in future riparian and fish habitat improvement programs.

In summary, we are looking for a good balance in our habitats: good diversity, food supplies, cover, good water quality and adequate stream flows to produce the chinook, steelhead and resident trout populations we desire.

Agencies, landowners and biologists must work as a team to reach sound land and water management goals that produce desirable benefits for all.

PLACER TAILINGS RECLAMATION AND HABITAT RESTORATION

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Today, I'd like to talk on fish habitat rehabilitation in placer tailings on the upper North Fork John Day River above Dale, Oregon, and Clear Creek which is a headwater tributary.

CLEAR CREEK PROJECT

First I'd like to discuss the Umatilla National Forest's Clear Creek project. The project area is located in the northeast corner of Grant County, Oregon on the extreme southeast corner of the North Fork John Day Ranger District, Umatilla National Forest in T.8S., R.35E., and T.9S., R.35E. The elevation at Clear Creek is between 4,500 and 4,800 feet. The annual streamflow fluctuates between 15 cfs and 500 cfs, although flows of over 1,000 cfs have been recorded.

A gold dredge went through Clear Creek. The dredge was a creek eater. He's the guy who did the damage. Of course, he also left something, and this is creek eater scat; we commonly call them dredge tailings. Prior to the project, you could stand in the depression in the tailings and hear the creek roar beneath you.

Dredging operations on Clear Creek began in the 1920s and had intermittent activity until 1954. This activity completely altered the natural hydrology of the stream. Prior to the rehabilitation efforts, the anadromous fish habitat in the area had not naturally recovered from the dredging activity.

Due to the major contribution this stream made to the anadromous fish runs in the John Day River System, it was recognized that rehabilitation work was needed to restore the dredged area.

Rehabilitation work has varied. From 1959 to 1961, the Oregon Department of Fish and Wildlife (ODFW) pushed 13,160 cubic yards of tailing piles into the stream in a total of 48 sites to provide spawning areas. This work was successful in that a very high percentage of the spawning took place on these sites. Prior to 1983, a number of attempts were made to establish willows by hand planting cuttings. These plantings had approximately five percent survival due to stream fluctuations and a limited amount of fertile soil along the stream.

The major fisheries rehabilitation work in the area has been on four miles of Clear Creek in 1979, 1981, 1982, 1983, and 1984. This has been a cooperative venture. ODFW has been heavily involved in the planning stages. Bonneville Power Administration has provided major financing since 1982 through the

Northwest Power Act. The Forest Service has been responsible for the planning and administration, as well as assisting in financing of the project. Due to the use of streams by steelhead and spring chinook salmon, the only period available for instream work is July 15 to August 31.

At the upper end of the project, Clear Creek flowed under the dredge piles for nearly a mile before surfacing again. This area of dry channel blocked year-round passage to approximately 22 miles of spring chinook salmon and summer steelhead spawning and rearing habitat upstream.

Therefore, the first objective was to get the streamflow back onto the surface and into the main channel. A channel change was used to keep the stream away from the tailing piles for 1,200 feet. Clear Creek was routed into a high water channel to the west of the tailing piles. Log weirs were constructed in a series using a crawler loader backhoe to provide a "fish ladder" that moved the fish past the blockage and kept the water in the stream channel. We worked in the dry as much as possible. These logs averaged three to four feet on the butt and were ponderosa pine or Douglas fir at this site. In Utah, Colorado, and Wyoming, ponderosa pine log weirs have lasted over 50 years. Hardware cloth was tacked along the upstream side of the logs to keep the current from scouring a hole underneath the log. A minimum amount of future maintenance was desired; therefore, the weir keyways were dug 15 feet into the banks and the banks armored with large riprap. The channel diversion and reworking of the streambed has retained much of the water in Clear Creek that previously disappeared under the dredge tailing piles, and anadromous fish have year-round access to an additional 22 miles of spawning and rearing habitat.

The second objective was to provide additional juvenile spring chinook rearing pools. Prior to our work, the riffle/pool ratio was 88:12, while optimum for spring chinook rearing has been deemed to be about 60 percent pool. For creating small pools, we use large boulders. The Forest's hydrologists predicted that the peak water velocities expected in Clear Creek are 16 to 20 feet a second, and the weight of a one cubic yard boulder is sufficient to prevent downstream movement. We use large excavators to place these boulders. It took an average of three to five minutes to place a boulder. Two years later, fish population sampling indicates that three to five pre-smolts a year are produced per boulder. A total of 82 log weirs provide medium sized rearing pools and the ten adult resting pools provide large rearing pools. When the area of the pools created by all of the structures constructed since 1980 are added to the pool habitat existing at that time, the pool percentage is estimated to approach 59 percent of the stream surface area. A physical survey is scheduled for Clear Creek during 1986 to tally both the area and volume of pools remaining two years after construction.

The third objective was to provide adult anadromous fish resting pools. The best resting pool is 15 feet deep. Two rock deflectors narrow the normal 25 foot wide stream channel over a center boulder which is seven feet across. Two four-foot diameter boulders are keyed in on either side of the center boulder and another row of large boulders is keyed into the bottom of the weir to prevent unraveling. The next winter the depth of the pool went from 12 feet to 15 feet, so several more boulders were placed in the pool to keep it from scouring deeper. This resting hole is presently 75 feet wide by 100 feet long and 15 feet deep. We have built ten adult anadromous fish resting pools in Clear Creek.

The fourth objective was to restore the riparian vegetation. The riparian vegetation hadn't recovered since the dredging occurred and planting cuttings by hand wasn't successful. An excavator was used to plant entire brush and tree clumps and large willow stems along the barren dredge tailings. Making sure the clump roots are in the low flow water table and transporting the soil with each clump has led to a high survival. Clumps that were planted in July 1984 still had a 100 percent survival rate in October 1985. We also planted large willow stems that averaged 15 feet in length and three to four inches in diameter at the base. We shoved the excavator bucket into the edge of the streambank about four feet and placed several stems in the slot created. All of the stems leafed out last summer, and they were still alive as of last October. More riparian work needs to be done.

The fifth objective was to curtail the flows from those mines on National Forest land that had heavy metals concentration. Chemical samples taken from the outfall of the Black Jack Mine had copper and zinc levels in the lethal range for salmonids. A three-foot thick concrete plug was placed in the entrance to the mine where seepage is collected and piped into the settling basin. Water samples taken in Clear Creek below the mine outfall show the concentrations of heavy metals have been reduced to within the tolerance levels of salmonids. Rehabilitation of hardrock mines is expensive. This project cost about $14 thousand and will require further expenditures when the settling pond fills.

The sixth objective was to increase the amount of gravel available for anadromous fish spawning. A physical survey which was conducted in the Clear Creek basin during August of 1980 found only 321 square yards of spawning gravel which was enough for 16 pairs of spring chinook salmon at the rate of 20 cubic yards per spawning pair. This was deemed to be insufficient spawning gravel for future escapement. An excavator was used to dig out the streambed to a depth of three to four feet and to fill the hole with one-half to three inch gravel screened from the dredge tailing piles. It was felt if we just threw the gravel in the stream, it would be flushed out by the first high water. Since 1982, 7,800 cubic yards of gravel have been placed at 182 sites. The spawning beds were located above and below the log weirs. The first fall, most of the salmon spawning in Clear Creek took place in the newly constructed spawning beds. In later years, none of the gravel beds placed above the log weirs were used by spawning fish even though spawning continued at the other sites. Above a log weir, the intergravel water flow after one winter of sediment deposition is evidently not sufficient enough to attract a spawning female spring chinook salmon.

Table 1. Summary of the Clear Creek Rehabilitation Project To Date

Item	1979	1981	1982	1983	1984	Total
Boulders Placed		2	100	600	74	702
Log Weirs	21	34	27			82
Log Deflectors		2	4			6
Rock Weirs			1		7	8
Rock Deflectors		4	3		17	24
Adult Holding Pools	3	1	6		1	10
Mine Plug		1				1
Mine Diversion			1			1
Spawning Gravel Beds	5		138	25	14	182
Cu. Yd. Spawning Gravel Placed	100		6,500	500	700	7,800
Erosion Structures			2	50	71	123
Hardwood Plantings		3		80	800	883
Total Costs (M $)	31	77	170	37	55	370

Results and Conclusions

The work area to date has been on a four mile stretch of Clear Creek and a two mile stretch of Granite Creek. The cost for the project from 1979 - 1984 totals approximately $370,000. The life expectancy of the project is thirty years.

The bottom line of this project is adult returns. Several observers saw over twenty adult spring chinook salmon in the large resting pool on Clear Creek during the summer of 1985. This was more fish in one resting hole than spawned in the four miles of the project the previous year. The ODFW is monitoring spawning populations of spring chinook in the four miles of the project area as well as in several control areas. The adult spawners returning from juveniles reared in the rehabilitated habitat on Clear Creek should steadily increase from 1985 to 1990.

NORTH FORK SIDE CHANNEL PROJECT

Another project on the North Fork John Day involved high flow channels created by gold dredging. Twenty-six side channels trapped rearing chinook parrs or pre-smolts annually. When the river level dropped, the channels dried up and the trapped fish died which resulted in an estimated loss to the system of 26,000 pre-smolt spring chinook salmon annually.

The project area is located in northern Grant County on the North Fork John Day Ranger District, Umatilla National Forest in T.6S., R.32E., and T.6 and 7S., R.33E.

Degradation by gold dredging in this area began in the 1930s and ended in 1950. Dredging activities changed the natural course and hydrology of the North Fork John Day River. To date the anadromous fish habitat in this portion of the river has not naturally recovered from the impacts of this dredging activity.

During August 1971, the Oregon Department of Fish and Wildlife (ODFW) in cooperation with the U.S. Forest Service increased the juvenile spring chinook rearing area by pushing dredge tailings into the river. This forced a portion of the streamflow down several secondary channels that were left dry by the dredging. From 1979 - 1985, the Umatilla National Forest rebuilt these two side channels and reopened an additional 24 side channels. The Forest also constructed structures in the river and side channels to increase juvenile spring chinook rearing habitat.

This has been a cooperative venture. ODFW has been heavily involved in the planning stages. The Louisiana-Pacific Corporation has made a source of boulders available to the project. Bonneville Power Administration provided major financing in 1983 and 1984 through the Northwest Power Act. The USFS has been responsible for the planning and administration as well as assisting in financing of the project. Due to the use of streams by steelhead and spring chinook salmon, the only period available for instream work is July 15 to August 31.

The overall project goal is to increase the production of spring chinook salmon by meeting the following objectives:

1. Decrease the hazard of juvenile salmon being trapped in the side channels during low flow periods. This has been accomplished by constructing structures at the channel entrances to provide a year-round streamflow through the channels.

2. Increase juvenile salmon rearing habitat in the mainstem river and side channels. Constructed pools below weirs and boulder placements are contributing to meeting this objective.

3. Improve Bank Stabilization. Rock deflectors and riprap were used to control erosion from unstable banks.

4. Increase adult salmon resting areas. The constructed pools below the main stem sills are being used by adult salmon for resting prior to spawning.

5. Restoration of riparian vegetation. Shrub cuttings and the placement of entire shrubs are being used to establish riparian vegetation along the barren dredge tailings.

Remaining work on the project consists of additional weir construction, boulder placement, bank stabilization, and shrub establishment and fertilization.

It is anticipated that the increased rearing area associated with the boulders, rock weirs, and side channels will result in increased anadromous fish survival from egg to smolt. This will require at least one generation of five years before results become readily apparent.

Table 2. Summary of the North Fork John Day Side Channel Project to Date

Item	1979	1980	1981	1982	1983	1984	1985	Total
Side Channels	1	8	1	1	6	3	6	26
Alcoves & Blind Channels							2	2
Boulders Placed	63	50	60	80	492	250	283	1278
Log Weirs						2		2
Rock Weirs			2		16	8	16	42
Main Stem Rock Sills							22	22
Rock Deflectors	14	3		1	4	7	23	52
Adult Holding Pools						1		1
Instream Logs Placed						1	35	36
Erosion Structures					4	1		5
Shrubs Planted							8	8
Cuttings Planted							182	182

FISHERIES HABITAT REHABILITATION ON AGRICULTURAL LAND IN ONTARIO

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Over the past several decades, many streams in Ontario have suffered degradation from agricultural activities. Some have been altered by dams, some modified by drainage, some trampled by livestock, others robbed of their stream-bank vegetation and others choked by excessive nutrients. These activities have resulted in a loss of fish habitat. For instance, as a result of this degradation, mid-summer water temperatures and stream sediment loads are elevated and instream cover is lacking for successful rearing of trout. Consequently, many streams have lost their natural capacity to produce trout.

Although there is not an economic value for this loss, it has been estimated that the loss in fish production from erosion and sedimentation problems alone amounts to $90,000,000 annually. Much of the cost from erosion and sedimentation damage is related to agricultural activities. To stop and reverse this loss, the Ontario Ministry of Natural Resources began a program of rehabilitating fisheries habitat on agricultural land.

The approach of the program is to work on the least degraded streams, and to do the simplest and easiest things first. The work is focused in the stream and up to the top of the bank or high water line. The work on the agricultural land above the high water line is undertaken by another government agency, the Ontario Ministry of Agriculture and Food. The program is a voluntary one and relies on the cooperation of landowners. The program provides incentives to farmers in the form of technical advice, materials and labor. When the target area has been selected, the Ministry enters into an agreement with the landowner to undertake the prescribed work on the property. For example, the Ministry may provide the materials for fencing livestock from the stream and the farmer agrees to install and maintain it. Or, in other cases, the Ministry may provide materials for the fence, install it, and the landowner agrees to maintain it.

The program began in 1979, has an annual budget of $200,000 and is concentrated in southwestern and central Ontario. The target species is primarily migratory rainbow trout populations. However, other species such as brook trout and brown trout also benefit from the work.

TECHNIQUES

Techniques that have been used to restore fish habitat on agricultural land include:

Fencing Livestock From the Water

The purpose is to protect fish habitat from trampling; to maintain buffer strips of vegetation along streambanks; to control erosion; to prevent deposition of sediment; and to prevent the impairment of water quality from livestock waste products. A variety of types of fence is used including the standard farm fence, barbed wire and electrical. Often it is also necessary to develop stream crossing sites for livestock and machinery. In addition, gates sometimes have to be installed along certain sections of the fence and bank stabilization work and reforestation on the fenced area are necessary. Regular maintenance of the fence is also required to ensure effectiveness particularly in areas with heavy snow loadings and floods. Stream crossing sites also require seasonal maintenance.

There is a variation in cost depending on the type of fence and the availability of local materials. Two and one-half metre steel posts cost $3.50 to $4.50 each; 15 cm diameter cedar posts are $3.50 to $5.00 each; and the larger posts for corners and braces cost $10.00. Standard farm fence wire costs $67/100 m coil. Single strand 13 gauge barbed wire costs $24/400 m coil and double strand 13 gauge barbed wire costs $40/400 m. The costs of establishing a stream crossing site depend on the width, depth and flow of the stream and the protection work required.

Planting Streamside Vegetation

The purpose is to stabilize streambanks, to reduce erosion of the streambank and sediment loading to the stream, to regulate streamflow and to reduce stream temperature. A mixture of grasses, shrubs and trees are planted. In some cases, it is desirable to have a zone of grass and shrubs close to the stream edge and trees planted further back from the bank. In other cases, where a bank cover is required, a mixture of grasses and legumes are planted close to the stream edge. In areas where it is necessary to establish shade as well as bank cover, shrubs and trees are planted. On headwater areas of the stream, trees are planted. Where streambanks are unstable, it is necessary to regrade the bank or stabilize it using riprap or other structures before planting vegetation on the streambank. In some cases, all that is required is to erect a fence allowing natural vegetation to establish itself.

The grasses planted are creeping red fescue, tall fescue or fall cereal rye. Legumes used are birdsfoot trefoil or crown vetch. Both these species have a long life and are adapted to a wide range of soils and moisture. Although dependent on local conditions, a recommended mixture for planting a grass/legume mixture is 20 to 30 kg/ha of grass seed and 15 to 20 kg/ha of legume. Without the legume, a grass seed of 50 to 150 kg/ha is recommended. A seed bed is prepared and a fertilizer is applied. A spring planting is recommended and a mulch is used. On steeper parts of the bank, it may be necessary to hold the mulch in place with pegged chicken wire or other suitable materials. A hand cyclone or hydro seeder is used to apply the seeds and fertilizer.

Shrubs planted are red osier dogwood, arctic willow, pussy willow, autumn olive and highbush cranberry. Trees planted include silver maple, white spruce and white cedar.

Protecting Streambanks With Riprap or Gabion Baskets

Riprap is applied where erosion is caused by surface runoff, subsurface seepage and the stream flow itself. Erosion on streambanks and stream bends with erodible soils are controlled with riprap. This structure is used where water flow velocities do not exceed 4 m/s and where submergence lasts continuously for more than a few days. The advantages of riprap are that it tolerates lateral seepage, provides immediate protection, is easy to install and repair and it is relatively inexpensive when stone is readily available. The disadvantages are the high cost if stone must be hauled any distance and it is labour intensive. On smaller streams that are subject to minimal changes in water levels, a more inexpensive log riprap is used. The advantages of this structure over riprap are that the cost of materials is low and that it blends into the natural setting.

Gabion basket lining is applied to streambanks that are steep, where slumping is being caused by either seepage or stream flow undercutting, or stone of sufficient size is not available for an adequate riprap lining. The advantages are that it can be used for a wide range of bank lengths, heights and shapes. The disadvantage is that it is expensive when compared with riprap.

Removing or Modifying Existing Dams That Block Fish Migration or Elevate Stream Temperatures

In some cases, the dam is removed or, a fishpass is installed. In other cases, a surface flow dam is converted to a bottom draw-off to provide colder water. This often involves improving the holding capacity of the pond so that the water may become thermally stratified. In other cases, a bypass channel is constructed to pass the majority of the stream flow from the retention pond.

Providing an Alternate Method for Taking Water for Irrigation

An intake device, consisting of a perforated pipe elevated from the streambed, is supplied to the farmer, reducing the need to dredge or dam the stream for irrigation water.

Altering the Practices of Constructing Drainage Ditches

To control erosion and decrease sedimentation during drain construction the following measures are being used: seeding the banks immediately following construction; leaving a buffer strip of vegetation along the watercourse; protecting field tile outlets with riprap; using riprap to control ditch bank erosion. A ditchbank will begin to scour where a tile outlet is directed on the bank. Riprapping the area above and below the tile outlet is a means of protecting the ditch bank from tile discharge.

Controlling Erosion on the Farmer's Field

The main types of control measures, applied by Ontario Ministry of Agriculture and Food, to offset the effects of overland flow are rock chutes, grassed waterways and drop inlets. Rock chutes allow surface water to flow from the field into the stream without harmful scouring. Grassed waterways allow water to move across fields via a protected route. Drop inlets are prefabricated structures set back from the stream edge to direct water from the stream bank to the stream bottom. They may be constructed of concrete, corrugated plastic or corrugated steel pipe. Concrete around the drop inlet provides protection against scouring.

Providing Spawning and Rearing Habitat for Salmonids

Wing deflectors and riprap are used to develop narrower and deeper channels. Rocks and half-log structures are used to develop instream cover. Substrate is added to streams for spawning.

Developing Demonstration Projects and Information Days

Several sites have been developed jointly with the Ontario Ministry of Agriculture and Food to demonstrate to the agricultural community the various techniques that can be used to control erosion and sedimentation, and rehabilitate fish habitat. Further, information exchange days and publications are used to point out the benefits to the farmer and the fishing fraternity that result from this work.

RESULTS AND DISCUSSION

Over 150 km of stream length have been rehabilitated during the past five years. Where there has been assessment, there has been reduction in the number of banks eroded, in stream sediment load and in mid-summer water temperatures. There has also been an increase in the amount of streamside vegetation and instream cover. Although assessment has been limited, at certain sites, mid-summer water temperatures have been reduced by several degrees. Further, stream sediment values have been lowered significantly. At index stations, biomass estimates for young-of-the-year rainbow trout have increased by a factor of 10 to 20. On several streams, after fencing to restrict livestock, rainbow trout are spawning where previously there was no spawning activity.

The program is an incentive one for farmers to cooperate. Unfortunately, all farmers are not cooperative. Or, some farmers want a greater incentive for their cooperation such as a tax reduction or a payment for the loss of crop that would result from the land taken out of production by the fence or streambank vegetation. Presently, the Ministry is not prepared to do this as it would penalize the more cooperative landowners. Consequently, work has not occurred at some sites even though they may be critical to increasing fish production. However, a regulatory program may not have been any more successful. Other studies have shown no difference in results between a regulatory and an incentive program to control non-point pollution.

Further, the work has been fragmented, directed at local problems and not systematic in approach. For instance, work has been done on over 30 different streams, but no stream has been completed from headwater to mouth. Consequently, significant and serious problems remain, while less serious ones receive attention. For example, work may be done to improve spawning and incubation habitat where there is no nursery habitat. Or, work may be done downstream to reduce sediment load where the upstream landowner has a serious gully erosion problem on his land. However, there is an attempt presently to take a more systematic approach to the problem and concentrate efforts on priority watersheds.

The habitat rehabilitation program is dependent on the Ontario Ministry of Agriculture and Food's (OMAF) program for reducing soil loss from the land. However, OMAF's priorities are not always located at the same areas as those for fisheries. Furthermore, where there are high levels of soil loss, the stream has been so badly degraded that it may not be economically feasible to restore it. It has been necessary also to wait for work to be completed on the land by OMAF before undertaking the fisheries work in the stream. However, there has been an increase in the awareness of each ministries' concerns as well as the mutual benefits that accrue to both agencies from good land conservation practices. Consequently, a more cooperative approach is being used to reduce soil loss from the land and restore fisheries habitat. Further, the rate of loss of fish habitat is diminishing as it is demonstrated that conservation practices result in a savings to the agricultural community.

Approximately one million dollars has been spent in the past five years to complete 150 projects. The average cost of a project is $5,000 with labour and materials comprising 64 percent and 36 percent of the total cost, respectively. However, five times the effort is required to restore fisheries habitat and recover the losses. Further, without additional funds, fewer new projects can be undertaken because many of the existing structures require maintenance costs. Although there is not enough money to do the job, there is some encouragement. The results show that rehabilitation can be successful. Furthermore, these projects demonstrate that there is an alternative to depending on expensive hatcheries for producing fish. This could result in a refocusing of our fish management efforts from one of hatchery dependence to one of habitat management.

B.C. PLACE FALSE CREEK SHORELINE REDEVELOPMENT

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INTRODUCTION

This paper presents the B.C. Place False Creek development with particular emphasis on marine shoreline redevelopment and habitat improvement, including planning, design, and construction aspects. The presentation touches on various aspects of False Creek, including its history, B.C. Place's role, objectives and its redevelopment process. A brief description of the existing (1980) marine environment and the planning, design, and construction processes are outlined in connection with foreshore development.

In essence, the intention is to provide the broadest possible perspective incorporating most of the relevant topics of concern in the process of redeveloping old industrial areas and their legacies. It should be noted that many other aspects of the site are dealt with in the comprehensive document, B.C. Place Overall Development Framework.

HISTORY

False Creek, in its original form, as shown on charts by Vancouver and Richard, was an extensive intertidal mudflat and marsh area into which some 18 streams flowed. The basin provided extensive habitat for fishery and wildlife resources. False Creek was first used by European settlers as a harbour for industrial access to tide water where filling and dredging were carried out to improve this protected waterway for Yaletown and the CPR Pacific terminus and lumber mills. Over the years, development diversified to include foundries, metal plating, B.C. Electric-Coal gas plant and ship building. This increased demand for land resulted in intensive alteration of the natural area through filling and dredging.

Today, False Creek is still evolving in terms of its use and urban characteristics. Emphasis is changing to residential and commercial uses as part of the development of the Vancouver urban core. Specific redevelopments include the City of Vancouver (south shore of False Creek), federal government (Granville Island) and provincial government (B.C. Place on north shore of False Creek).

REDEVELOPMENT PERSPECTIVE

B.C. Place Ltd.'s objectives are to develop some 180 acres along the north shore of False Creek into an urban centre accommodating development into the 21st century. Waterfront is a key element in this project and the planning was carried out to maximize that resource within existing physical and institutional constraints. In this connection, water quality and shoreline improvement are important elements.

Another objective was to redevelop the area to contribute to the revitalization of the urban core to optimize recreational access to a water area that has had historically limited access due to heavy industrial use.

Numerous studies were carried out in connection with site services, such as storm water and related discharges to reduce water quality effects and improve shoreline usage. Shoreline improvement was oriented to maximize upland usage and development areas but with consideration to the marine side, incorporating a diversity of shoreline types, alignments, slopes and materials.

The redevelopment process involved all levels of government; municipal, regional, provincial and federal.

DEVELOPMENT OBJECTIVES

A variety of development objectives were imposed on the redevelopment of the shoreline. The City of Vancouver required that the surface area of the inlet itself be maintained and shoreline length maximized. There was interest in a continuity and diversity in the seawall structure which also accommodated land development. Marine access was also to be maintained with a high emphasis on the broadest possible range of recreational opportunities. The redevelopment process, therefore, fit within these objectives to establish a shoreline with an urban character with improved environmental and aesthetic values, as well as market values.

Part of this naturally included the removal of and cleanup of the shoreline and the removal of urban sediments from selected areas of False Creek. The sediments in particular were severely contaminated with inorganic and organic pollutants (Table 1) such that marine floral and faunal development appeared limited.

In terms of fisheries habitat improvement and enhancement opportunities, the objectives were to maintain existing fish habitat, improve degraded habitats and create new habitat. Measures considered included the improvement of intertidal and subtidal habitat by contaminated sediment removal, stabilizing the shoreline and diversifying the types of substrate.

In terms of water improvement, measures were undertaken to enhance the flushing characteristics of the east basin where pollutant buildup has been extensive and could continue in the future (Table 2). Further, storm water discharges were consolidated and relocated.

The focus of redevelopment, because of the urban industrial characteristics, was on aesthetic improvement and passive and active recreation. Associated with these objectives, habitat improvements came about as the creek bottom and shoreline were dredged and the shoreline stabilized.

EXISTING MARINE ENVIRONMENT

In order to better understand the False Creek environment, a number of studies were undertaken. These included storm sewer design and management, soils and marine sediment studies, assessment of dredging effects, fish collection and identification, fish catch effort evaluation, sediment leachate analysis, water quality assessment, bioassays and hydraulic evaluation of the inlet system.

Physical/Chemical Aspects

In terms of the physical/chemical aspects of the marine habitat, the substrate was the most studied. The intertidal zone consisted largely of loose heterogeneous fills and the subtidal zone consisted of 2 m or more of black organic sediments overlying grey marine silts and clays.

The intertidal muds were anaerobic and did not exhibit a great diversity of life. A summary of sediment contamination is shown in Table 2.

Table 1. Average* levels of Cadmium and Mercury in the surface and subsurface sediments of False Creek[1]

	Cadmium (ppm)	Mercury (ppm)
West of Cambie Street		
Surface	0.9	0.5
Subsurface	< 0.3	< 0.2
East of Cambie Street		
Surface	3.1	1.2
Subsurface	< 0.5	< 0.2
Ocean Dumping Criteria	0.6	0.75
Range of Global Background levels	.3-17	-

* includes the values (less than detectable limits).

[1] Based on data from a joint program in December 1982 by B.C. Place, Ministry of Environment and Environmental Protection Service including 110 samples of which 31 are east of Cambie Street Bridge.

Table 2. False Creek Water Quality

Parameter	Units	Under Burrard Bridge 50 Percentile	Under Burrard Bridge 90 Percentile	Under Cambie Bridge 50 Percentile	Under Cambie Bridge 90 Percentile	Typical or Objective Value
Physical						
Temperature	^{o}C	10.	18.	10.5	18.7	10
pH	-	7.8	8.2	7.8	8.1	7-9
Turbidity	NTU	2.15	5.81	1.9	6.1	5-50
Secchi Disc	m	2.44	4.08	1.75	3.58	1.2
Chemical						
Dissolved Oxygen	mg/l	7.85	10.	8.	9.89	5
Nitrate	mg/l	0.23	0.37	0.17	0.35	.25
Phosphate, total	mg/l	0.063	0.081	0.064	0.085	.05
Tannins & Lignins	mg/l	0.2	0.4	0.2	0.4	-
Cadmium, total	mg/l	<0.0005	0.0012	<0.0005	0.0007	.005
Chromium, total	mg/l	<0.005	0.009	<0.005	<0.005	.04
Copper, total	mg/l	0.002	0.010	0.002	0.007	.01
Lead, total	mg/l	<0.001	0.007	0.003	0.008	.01
Mercury, dissolved	mg/l	<0.0005	0.00014	<0.00005	0.00019	.001
Nickel, total	mg/l	<0.01	<0.01	<0.01	<0.01	.25
Zinc, total	mg/l	0.0145	0.0609	0.034	0.104	.10
Bacterial						
Fecal Coliform	MPN	120	1494	340	3500	
Total Coliform	MPN	1300	22520	2400	24000	<200

NOTE:

a) 90 Percentile--90% of the data is less than or equal to this level. 50 Percentile--50% of the data is less than or equal to this level.

b) Data from British Columbia Ministry of Environment False Creek water quality sampling program from June, 1972 to December, 1977 at the Cambie Street Bridge sampling site and from June, 1972 to August, 1980 at the Burrard Street Bridge sampling site.

The inlet water is marine and influenced by urban runoff, including combined sewer flows and storm water runoff. The inlet system has an exchange rate of approximately six tidal cycles; that is, it takes six tidal cycles to replace the water in False Creek with that of English Bay. Studies undertaken to date show that, from a fishery quality standpoint, it is acceptable although there are periods of high temperature and low dissolved oxygen. There is insufficient information to comment on the inorganic and organic constituents; however, bacteriologically, the area generally exceeds health criteria for primary contact recreational uses. A summary of information is shown in Table 1.

Biological Aspects

The intertidal habitat appears to be typical of shallow freshwater influenced marine inlets, supporting a variety of marine flora and fauna. However, the general substrate instability and asphaltic mixtures, which make up much of the shore, limit biota attachment.

The subtidal habitat supports an impoverished benthic flora and fauna. Epibenthic fauna appears to be limited to shrimp and crab which were, at times, found in moderate abundance in the central area of False Creek but low abundance in the east basin.

A variety of pelagic and bottom dwelling fishes were observed, including juvenile salmon, herring, smelt, anchovy, sculpin, greenling, dog fish, stickleback and flounder. Based on casual observation of the water in the inlet over several months, there is also phyto and zooplankton also occurring in some abundance. Again, few fish were encountered in the east basin.

PLANNING, DESIGN AND CONSTRUCTION OF THE SEAWALL

The following is a brief outline of the staging of the redevelopment.

It was originally planned to undertake a coordinated joint effort for a broad, creek wide cleanup of sediments and industry waste removal such as the City of Vancouver proposed in 1972. However, because of the timing constraints, this opportunity was not brought to fruition.

While the B.C. Place concept was to maximize land and thus people use of the site, the planners developed several concepts from which one that met all objectives was selected. A mix of shoreline types was emphasized in the plan, including rocky shore, sheet pile, step walls, circular walls and beach, reflecting the types used in other developments elsewhere, including San Francisco, New York and Vancouver. The mix of shoreline types is planned to be 50 percent riprap, 25 percent sheet pile, 15 percent beach and 10 percent concrete wall.

Incorporated in this mix are plans for a fishing pier, again emphasizing people use of the area and access to water.

The planning and design process involved architects and urban designers, B.C. Place staff, public advisory committees, the City of Vancouver and other institutional elements, giving consideration to municipal and regional bylaws and needs, provincial and federal requirements and statutes. While their collective interest was site wide in general, specific upland influences and shoreline concerns affected the seawall form. Once the seawall form was established informally, appropriate regulatory approvals were obtained, but not without further refinements to meet specific interest or regulatory group needs.

Because of the intended use of the upland areas, a structurally sound seawall edge was required. Models were developed and enhancement measures emphasized shore and bottom improvement through stabilization and contaminated sediment removal.

Construction of the seawall involved soil and sediment handling and, in this connection, alternative methods of sediment disposal were investigated. Normally, marine sediments which meet Ocean Dumping Control Act (ODCA) guidelines are disposed at a local dump site seven km west of Point Grey; however, the nature of the sediments from False Creek required special treatment and disposal. Alternative disposal sites considered were False Creek, Point Grey, landfill, chemical treatment, or deep ocean. The latter was selected for the bulk of contaminated surface sediments.

Considerable effort was expended in liaising and coordinating site needs for regulatory agencies to minimize disruption to the environment and construction. Numerous meetings and discussions were held with Environment Canada, Fisheries and Oceans, and the Provincial Waste Management Branch on the dredging and dumping activities. Environmental monitoring programs were set up and the seawall was reviewed with DFO's Habitat Group to optimize opportunities for habitat improvement along the north shore of False Creek. Evaluation of dredging effects showed only localized temporary effects.

While this discussion generally deals with B.C. Place plans in the long-term, it is noteworthy that in the short-term, the B.C. Place area is the site for Expo 86 and, as such, many of the long-term objectives and needs will be on hold until the end of 1986. The plan for the remainder of the shoreline improvement will then be implemented.

In wrapping up this presentation, one should note that there will likely be a marked improvement in the general quality of the False Creek environment with its transition from industrial to residential/commercial use and, like the strongly developed intertidal biota on the south shore, where improvements were made 10 years ago, an enriched biota on the north shore will develop. Considering False Creek's recent history, it is apparent that marked improvements have been made; however, a large amount of contaminated sediments still exist in the creek and improvements to storm water quality are required.

EPILOGUE

Since the construction of western portions of the seawall in 1983 - 84, there has been remarkable colonization of the low intertidal and subtidal zones, particularly on the riprap faces. A variety of algae and sedentary fauna have attached, including laminaria, ulva, barnacles, and blue mussel. Hopefully, assessment of fishery resources in the future will show the area to be a productive habitat supporting a diversity of species.

INSTITUTIONAL FRAMEWORK FOR HABITAT IMPROVEMENT IMPLEMENTATION

G. Ross Peterson
Howard Paish & Associates Ltd.
Vancouver, B.C.

I'd like you to consider my talk an extension of Duncan Hay's discussion yesterday, where he emphasized the importance of recognizing controls. Where he was talking about physical controls on hydraulic processes, I will talk about institutional controls that can be just as deterministic in what you can and can't do. But in the case of institutional mechanisms, we can see ways to take advantage of some, change some, or even create new ones--a decided advantage over Duncan's more inflexible physical controls.

Duncan referred to these as "knobs you want to turn." The trick here is to know how to recognize them and understand them well enough to know, on the one hand where opportunities lie, and on the other, where no influence can be exercised. Remember, effective management means control, and effective management decisions mean knowledge of controls.

I am going to discuss institutional mechanisms from two perspectives: institutional understanding for successful habitat improvement; institutional arrangements as a habitat improvement technique.

INSTITUTIONAL UNDERSTANDING FOR SUCCESSFUL HABITAT IMPROVEMENT

A necessary part of habitat improvement planning and selection of sites is the identification of the controlling mechanisms in the watershed. Who controls land use, water use and water quality can be just as important as a detailed bio-reconnaissance; perhaps even more so if a significant risk is found. Security for an improvement investment should be dealt with in the same way that a banker considers a loan. What are the risks, what is the guarantee that you are going to get your money back? Obviously, this is of greatest importance when large financial commitments are involved.

Manageability is the key to success, and a thorough assessment of risk will show you how manageable your program is. Knowing how to assign risk, and how to make decisions based on this risk, are steps that the improvement planner must know or must learn how to do. Importantly, you must know when to back away from a high risk site where you don't have control, and to do it responsibly.

The choice will sometimes be faced: when a high risk is identified, do you go elsewhere, or do you lower the risk through affecting some level of control or influence on those in control? There will not always be easy answers, but the more thorough the understanding of the controlling mechanisms, the better the choice will be in terms of improvement security and site selection.

As an example, would it be worth improving habitat below a mine effluent site anywhere in B.C., where federal DFO has little direct control over provincial permits and licences? Does it trust the Province to look after its interests? Or should DFO go elsewhere? At what point does the risk become acceptable? With acceptable Provincial Waste Management permits? At what point do you intercept the mine planning process to attempt to instil some federal controls? The question here is, do you know how much control or influence you can actually affect and therefore do you know by how much you can reduce the risk? Clearly, the more you can understand the total institutional framework controlling land and water use, the better off you'll be in understanding the risks posed to your improvement and how to reduce them to levels acceptable for your project.

Have you ever approached the issue of risk in a systematic fashion? It should become a primary ingredient in all improvement planning for justifying specific projects and selecting sites for projects.

INSTITUTIONAL ARRANGEMENTS AS A HABITAT IMPROVEMENT TECHNIQUE

The goal here is to improve habitats or avoid (further) losses of habitat through altering or strengthening institutional arrangements with watershed planners, zoning authorities, or landowners.

This is more than a fancier name for habitat protection, if one considers the choices for stream and watershed management. Remember, there are few cases where the fisheries manager will have the watershed to himself for growing fish. Choice of management style will almost always be influenced by the total set of resource and planning strategies found in the watershed. Hopefully, these other interests will only influence and not dictate fisheries management style, but the choice will be mainly up to the fisheries manager.

One scenario will have management by reaction to other users' development plans. There will be little opportunity to gain in habitat use or quality from this approach (as there will be little security and high risk), and chances are great that there will be an annual loss, even with heavy enforcement effort.

A more active approach to management, putting the fish manager in an anticipatory and planning mode, can open up many opportunities for improvements, simply because of the goal setting, the understanding of the other competing and complementary resource interests and the assertion of some level of control that are essential parts of the proactive approach to management.

Let's turn to a working example, the Salmon River at Langley, B.C. A program funded by the Salmonid Enhancement Program was undertaken on the Salmon River to put into place a working cooperative watershed planning and management system. This is a largely agricultural watershed facing imminent urban development. It was perceived by us, the contractors, and SEP that in a watershed such as this, normal habitat protection as characterized by enforcement and referral response would not provide adequate protection of the river, and would not protect options for future improvements of coho and trout habitat. Simply put, reactive management wouldn't do the job.

In examining the options for a more active style of management, it became apparent that existing institutional mechanisms, properly massaged, could go a long way to maintaining and even improving habitats that would surely be degraded or lost altogether by development impacts.

What focused our attention on this was our perception of what the overall fish management goals ought to be in a watershed facing large scale urban development. Certainly, fish production is still a goal, but even more, the production of the species mix, and in a manner that the urban dweller can identify with, are important goals for a watershed in this setting. We therefore considered that urban dwellers' personal use and enjoyment of a natural streamcourse and its fish populations had to be respected and even encouraged as legitimate goals for fish management. Also, peoples' proprietary right to use and enjoy their private property had to be respected, particularly properties adjacent to the stream. Importantly, we did not consider these to be in conflict with good fish and habitat management and protection of improvement options. In fact, it is our belief that fish and people deserve the best from each other, and that institutional mechanisms which separate them are not only contrary to peoples' property rights and freedoms, but are also closing off the means for effective and cheap habitat protection, and challenging opportunities for improvements.

Breaking it down to its simplest form, management can either oppose the public use (and challenge legal rights) or it can work with the public, who it shouldn't surprise you to know, love fish every bit as much as you do, and are already on your side in terms of wanting to protect natural streamcourses. If you need proof of this, look at real estate ads and property values. See how much of a premium there is on stream-side property.

In fact, we questioned all stream-side landowners (farmers, urban dwellers) on the Salmon River to get their attitudes on stream protection and improvements. The response reinforced our belief that nobody hates fish, and further, that a majority would not only like improvements made, but would like to contribute their own efforts to see it happen (some were rather forceful in this regard) and we strongly suspect that this attitude is general in all such watersheds.

With all this positive energy going for us, why don't we have superbly managed urban streams, alive with self-starting enhancement projects? The answer in large part, lies in the institutional structure and the production-only philosophy of overall fisheries management--a cumbersome system that chokes off the opportunity for individual or local-style management tailored to local needs, values, rights and use patterns for urban streams.

THE KEY

The most effective and meaningful management of small urban systems will be built around, or at least incorporate, local needs, uses, values and rights. Management of these small systems from Ottawa and Victoria simply won't allow enough local color.

Ideally, these local goals should be cooperatively established on a full watershed basis (watershed use goals, water management plans), that take into account opportunities for more local control.

I remind you that cooperative management can only be instituted when common goals can be set. For example, an urban developer can have the same goal of protecting "natural streamcourses" for his own property value protection purposes, as the fish manager has for producing fish. The motives may be different, but the goal is the same.

Let me expand a bit on goals and management priorities. With urban streams which have a relatively low fish production potential, the fish manager will be hard pressed to justify much time and effort for their management, particularly with more and more pressure put on him to deal with larger fish producing systems.

However, at the same time he will often recognize that he will have to respond somehow to the growing social and educational demands that are characteristic of these systems. In these situations, there will often be advantages in turning over part of the habitat management role to more local control, ideally within some form of cooperative management framework with the local planning authority (i.e. municipal government).

There are some obvious difficulties with managers giving up, or being seen to be giving up, any authority in favor of more local control. What kind of local control is possible, and how can this natural reluctance to turn over control be overcome? Aside from the philosophical shift to accept a more local brand of management, there are several institutional steps that can be taken in concert with other regulatory agencies, municipal governments, and landowners towards cooperative planning that can lead to win/win situations and make this jump easier. It is important in cooperative planning that there be no obvious losers, or we are back to polarized, adversarial management again. Since everyone loves fish--even the land developer who makes more money when natural stream character is protected, and the municipal government which reaps more tax revenue from high property values--why can't we develop a system that allows us all to have our cake and eat it too? Impossible? Not at all: especially if we start soon enough, before anyone can visualize losses; and when all options are open for protection and improvement.

Let's look at how the existing institutional framework was adapted for cooperative resource management of the Salmon River.

First of all, the governments have to get their act together. Clear goals have to be expressed for fish production and habitat management--a sense of purpose and direction--followed by a realistic assessment of the relative importance of various habitats so that a focus could be put on the most important stream areas. This habitat priorizing is then overlain with specific development plans from the municipality so that areas of potential conflict can be identified, along with some sense of development scheduling. From this, specific habitat protection and improvement plans and scheduling can be drafted. So far, this seems nothing more than a refinement process for habitat protection, so where's the cooperative element? Cooperative planning is exercised first of all in joint recognition of important habitats, which not coincidentally, are almost always those favored as attractive settings for residential development. Depending on philosophy, this situation is either troublesome or advantageous. More importantly, the next steps in planning and protecting these sites are done in a true cooperative fashion. This can and has involved measures ranging all the way from simple setbacks for protection, to municipally handled enforcement, through incorporation of specific plans and stream protection measures into municipal bylaws. This is using the existing institutional system to great advantage, and has not involved any radical change or new institutions.

To get back to the theme of this workshop, we see this type of institutional arrangement as achieving a net benefit in habitat condition, certainly over what would otherwise be achieved through more traditional approaches, and opens the door to a host of small to moderate scale improvement projects; again which might be foregone with traditional protection treatments.

Full development of this type of cooperative planning program will require that government, both federal and provincial, speak with one voice on stream protection needs and requirements (for example, the setback distances that appear in a number of guideline documents of several agencies). To the municipal planner, government is government, and government stream protection should be the same regardless who he is speaking to. This was resolved in Langley by a "top-of-bank flagging" exercise involving an early joint determination of an appropriate setback by representives of all agencies before land zoned for development is acquired by developers. This is an investment in planning of a fraction of the time that would otherwise be spent on repeated inspections before, during and after subdivision development. The municipality now has a surveyed line that it enforces throughout development, with no further government referral or inspection needed. So, with this system, the municipality does most of the protecting and enforcement.

Where does this program now stand?

The program stopped short of full community involvement and even full interagency involvement, because prior senior government commitments have not yet been made on the adoption of the concept of cooperative watershed management.

For those who may question whether this cooperative planning and management approach is really a habitat improvement technique, let me close by telling you that in terms of cost, the safeguarding by the cooperative management program of the continued production of existing stocks and their improvements (which we assumed would otherwise be lost to development effects) approximated the cost of producing an equivalent number of adult fish by low technology production facilities and was a quarter or so of the cost of production by hatchery means. This relatively low cost, when added to the social benefits of maintaining a natural streamcourse in an urban setting, demonstrates that cooperative resource planning and management can be an effective improvement technique.

In its application to other types of watersheds with other resource development or industrial mixes, we believe this cooperative management approach would be just as effective, although there would be fewer opportunities for cooperatively set goals with intensive industrial users.

THE ECONOMIST'S ROLE IN HABITAT RESTORATION

Paul Kopas
Habitat Economist
Habitat Management Division, DFO

As the last speaker, and as a non-biologist, I must say that I have found the proceedings of the last couple of days to be very interesting and informative. Over the past two-and-a-half days, I have heard many people stressing the importance of evaluation while recognizing the biological and technical difficulties in doing so. Often, evaluation has referred to biological measures such as production of benthic organisms or, of fish. Many people took the idea of evaluation further and referred to economic evaluation in terms of benefit/cost analysis and cost-effectiveness analysis. There were suggestions that project selection should even be partly or wholly determined by its economic return. Brian Tutty asked why money spent on the Pacific Coast Terminals' site and on Gundersen Slough was not spent on habitat that had more productive potential. Gerry Taylor suggested that benefit/cost ratios be used in comparing techniques and gave us a list of techniques ranked on the basis of benefit/cost ratios.

This emphasis on evaluation demands the question, "what are the benefits of habitat restoration and improvement?" What, indeed, are the objectives of undertaking these projects. John Patterson asked, in his introductory remarks, that each speaker evaluate his project in terms of fish production. But is that our only objective? I think not.

While a set of objectives has not been set out in detail, many have been specified and others implied. I would suggest that the following is a probable list of our objectives: opportunities for cooperation; no net loss; research; pilot projects; preferred species enhancement; economic and social benefits.

OPPORTUNITIES FOR COOPERATION

While John emphasized fish production, Tom Bird recognized that some projects will be undertaken even where we cannot measure fish production. One of our objectives is to establish a good cooperative process with private industry or another level of government.

NO NET LOSS

At the no net loss workshop a year ago, a distinction was made between the application of the no net loss policy and habitat restoration. However, the distinction is not always clear and some habitat restoration may be initiated as a result of no net loss application.

RESEARCH

Some projects will have a large research component and may even be undertaken for that reason alone.

PILOT PROJECTS

Some projects will be undertaken simply as pilots as we learn how to apply relatively new technologies.

PREFERRED SPECIES ENHANCEMENT

Allocation among user groups is a major issue facing DFO management today. In particular, chinook stocks are in a seriously depressed condition. Our restoration and improvement projects might target on habitat features for preferred species.

ECONOMIC AND SOCIAL BENEFITS

DFO's mandate is to conserve, protect and manage the fisheries resource for the social and economic benefit of Canadians. Fish production is ultimately for social and economic benefits, and projects that have greater benefits would normally be preferred to those which have lower ones.

What we need is a process to select projects according to some consistent set of criteria. This is particularly so because some of the objectives I listed may be in conflict. Economic analysis has two important roles to play in habitat restoration/improvement program selection.

First, economic analysis can rank projects according to their benefit/cost ratios or lowest cost in cost-effectiveness analysis. Those with highest ratios or lowest costs, respectively, would be preferred. I would like to comment at this point that benefit/cost analysis and cost-effectiveness analysis are not the same thing, though they were used interchangeably by several previous speakers. Where fish production can be reasonably quantified, a benefit/cost analysis is the appropriate technique, but where fish production cannot be quantified, yet projects are felt to be desirable because of say, opportunities for cooperation with industry, then cost-effectiveness analysis would be used.

Second, economic analysis plays a major role in program rationale. The Salmonid Enhancement Program is presently in a transition phase and it has been suggested that habitat improvement projects, or some kinds of habitat improvement projects, may be the emphasis of a new enhancement program. The assessment of SEP small projects by D.B. Lister showed that these projects have long-term benefits with limited operating costs. In presenting a program of this sort to Treasury Board and Cabinet, detailed benefit/cost analyses will be required. It is important that the appropriate information and analyses are consistently presented to these decision-makers.

It is extremely important that economic analyses are done consistently. Last week, I attended a meeting of resource managers and economists from five resource agencies. The meeting was to try to resolve real or perceived differences among economic analyses done in different agencies. It is very frustrating for managers to work for several months on an analysis, only to have another agency bounce off the walls because the economics was poorly done. One of the central problems identified was that economic analyses were being attempted by people who were not economists.

I therefore find it rather ironic that the C.O.R.E. award, or "Counselling On Reckless Economics", was initiated by a biologist. In this context, I am also concerned about some of the benefit/cost ratios presented. I am extremely skeptical about benefit/cost ratios of 12:1 or 27:1. A benefit/cost ratio of 5:1 is very high while the 1.7:1 average for SEP small projects is respectable. Private sector companies undertake investments when the benefit/cost ratio is about 1.3:1.

A promising new area where economists and biologists can work together is the development of new evaluative methods. The Habitat Management Division has been working on a salmon production model called SHEM or Salmon Habitat Evaluation Model. SHEM models the lifecycle of the salmon using biostandards such as number of eggs per female and spawning area required per female. Variables such as pool-to-riffle ratios and spawning-to-incubation flow ratios are applied to survival rates. Each life stage, from spawning through egg, fry and smolt survival, are modelled using habitat factors as constraints. More work needs to be done on estuarine and ocean survival. Also, the model now developed for one species on one river must be expanded for all five salmon species and a range of river systems.

The returning adults in the model are separated into harvest and escapement. The harvest is then treated in a benefit/cost analysis which follows the biological component of the model.

With this type of a model, we should be able to evaluate such techniques as large debris placement, gabion weirs, flow control, temperature control and others. More work is needed on estuaries but the model eventually should be able to evaluate eelgrass transplants and island placement in estuaries as well.

This model runs on Visicalc, presently on an Apple computer, so it can be readily used by a wide number of people. When fully developed, all fisheries-related people would simply need to put in the required habitat information about their project to have both a biological and economic evaluation.

The economists take project and program evaluations and combine them with socio-economic information in a multiple account system. Recognizing that economic efficiency, that is, benefit/cost ratios greater than one, is only one decision-making criterion, the DFO has used a five account system to measure the impact of fish production on other social variables. The present accounts in our system are national income, employment, Native involvement, environment, and community development.

The national income account contains the benefit/cost analysis while the others review the effect of fish production on those other subjects. A multiple account system could theoretically include other subjects that have an important bearing on project and program selection.

Where do we go from here?

Obviously, we continue to do research and refine our techniques.

We must define and agree on our objectives and we must develop a process to choose among projects that have conflicting objectives.

I would like to reiterate John Patterson's request to evaluate projects in terms of fish production. Other measures are important as part of the learning and development process but both biological and economic evaluation needs figures on fish production.

Further work on evaluative techniques, such as the final development of SHEM, needs to be done. Habitat models could be developed for other species as well, particularly for shellfish and other species that may be raised in mariculture.

There needs to be an early involvement of economists in habitat restoration and improvement project and program design. To properly evaluate a project, an economist needs to understand it. Furthermore, the type of data generated without the economists' input often does not lend itself to economic analysis. Early involvement of economists would allow for data collection to be designed to meet the needs of economic analysis. This analysis will give us an important measure to know if we are meeting our objectives.

QUESTIONS AND DISCUSSION
ON
ALL SESSION V PRESENTATIONS

(James Buell, Consulting Biologist): I like the idea of the knobs-to-turn analogy. It's certainly a lot better than the often used term, buttons to push. Buttons are usually on/off control devices, whereas knobs are connected to rheostats. The skill in the business is not knowing just which knobs to turn, but how far to turn them.

If I can carry the electrical analogy a little further, in order to make a system work well, one must balance the voltages and the resistences, and the capacitances, to get the right frequency to tune in on, either to send or receive.

As far as developments are concerned, especially in urban salmon streams, developers love to make promises, especially early on.

For fisheries people, get the promises in writing, but, don't make the developers make promises they can't keep. You've got to exercise a little responsibility. Hold them to their promises, reasonably. If they run into a situation where they simply can't keep their promise, you've got to be flexible.

When it's all over, if the developer has kept most of his promises and things are turning out pretty well, give him his due, give him the credit, that's what he's really after.

If you want to keep working with the public, or the private sector, it's very important, especially to the people who are developers, that they feel they've accomplished something on behalf of the fish. Sell your product, the fish, and habitat. Developers are not very clever, really, especially when it comes to fish. The fisheries managers have the hammer, use it, but don't bend the nail.

Lastly, a very important item; do not be a moving target.

All of a sudden you'll find that developers will start getting real serious, and they'll start going around you. They'll go straight to the top, they'll go to legislators, they'll go to senior administrators, and the guy out there on the ground is going to get stepped on. You won't be able to meet your goals, it's happened in the States. I don't know if it's happened here. There are some agencies who have had their jurisdiction pulled back, and that's extremely unfortunate.

If you say things, you want people to listen. Credibility is very important. If people aren't listening to you any more because you haven't been credible, it doesn't matter what you say, it doesn't matter what your message is, it won't get across. Be credible, don't be a moving target.

(Colin Levings, FRB, West Vancouver): We've heard a lot about an evaluation of these projects, and I'm certainly in favor of this. I'd like some comments from some of the Oregon people in particular, as to what criteria they use for evaluation. From the range of studies they're doing, they've done possibly more evaluation than what we've done locally.

On fish production, there was a comment in the Oregon situation where there weren't enough fish escaping to get in to use these restored habitats. I also gathered from the Washington people that they're more tied in with the harvest management strategy. Once again, if the fish are being taken in a fishery and not being allowed to escape, then a lot of our restoration projects are certainly not going to be too useful. Is there a rule of thumb that the Oregon people use for evaluation?

(Errol Claire): In Oregon, we had taken some of the production information that we had on some of these streams that we've worked on, and worked with Fred Everst in terms of looking at the cost of fencing, for instance, in relation to steelhead production. Fences cost us, at that time, $2,000 to $2,500 per linear mile. On some of the small headwater production streams, yearly maintenance is $300. The benefit/cost on the $2,000 per mile fence is about 3:1, 4:1. At $2,500 a mile, it's about 2.14 to 1. Depending on the site, you don't normally have a maintenance cost of $300 a year, but maintenance has to be figured into your program. That's one thing that you don't want to forget.

(John Andrews): As to adequate escapement in the John Day Basin, where we directed our comments today, we have only three downstream dams, and we've got pretty fair escapement there. The areas we were working in, are fairly well seeded. We took a four mile stretch and expanded it upstream. We found fish up through these areas.

We do have another area in the Grande Ronde, where it comes into Snake River at Lewiston, Idaho, where there is a problem. We weren't going to do anything there. Then we realized we have to take the fish that we do have coming back, and ensure they have every opportunity for as much success as they can, increasing the survival. If we don't we won't have them. All we'll have is a hatchery product, we won't have the wild gene pool any more. They're going to be gone in about two or three generations if we don't do something. So we've taken one little steelhead stream and increased survival significantly on that stream because of that reason.

(Levings): How do you tell how long you're going to evaluate a project? You had a 184 percent increase in some of the riparian habitat that seemed to be the average for about five studies. Does that just happen by chance, or do you say, there's going to be five studies; they're going to be long enough to evaluate a doubling of smolt production, or whatever?

(Claire): Under the BPA Program, we have a research division that's handling that segment of it. If they're under contract to BPA they're looking at about five years of evaluation time, and what they're going to attempt to do is take and equate it out to numbers; numbers of smolts produced, adult returns, and then compute it.

Ultimately, we expect to compute economic values, but we're looking at about a five year period.

The average length of studies has varied from two to five years. Our study on Camp Creek is still in progress and we've been at that eleven years.

As to our approach on habitat and escapement, what we're saying is that we're working on escapement problems under some other programs, and we want those fish to have some habitat when we get some of the other problems solved.

We have a big Snake River enhancement program going on in northeastern Oregon. They don't have the escapement. They're going to a hatchery program, but they're also moving into an extensive habitat improvement program. We want the habitat there, when the other problems are taken care of. We're optimists, we think they're going to be taken care of to a fairly high degree.

(Tom Chamberlain, MOE, Victoria): How do you put a value on the steelhead?

(Claire): Basically, we're using National Marine Fisheries evaluation studies as a base for our up-river values. They have computed values for up-river summer run steelhead, spring, chinook and fall chinook in the upper basin.

(Chamberlain): How is it done?

(Buell): I think I can simplify it a little bit. I made mention the other day that we got $550 for spring chinook as a value, and that blows everybody's mind. Nobody can get a dockside price of $550 no matter how big the fish is.

To arrive at that figure, economists take the number of fish that enter the fishery, either the sport or commercial fishery. They figure the dockside price, or the amount of money spent by the sport fishermen in fishing for those fish. All the various costs are added in and escapements figured. They then end up with what they say the fish is worth.

A three to one catch to escapement ratio means, according to the formula, that one-quarter of the fish are absolutely worthless. They have no value whatsoever because they're not caught. That's baloney from my perspective.

A much better philosophy is that the value of the work, particularly when it comes to enhancement, or rehabilitation, or any of the stuff we're talking about, should be computed in terms of the number of adult returning spawners.

In other words, a returning spawner which has no value to the fishery any more, can produce other fish which will be caught.

For example, if one pair of fish can return ten fish to the fishery, plus its replacement fish, then that fish is worth five times the average price that the economist would attribute, either as a sport or commercial caught fish.

Fish make fish, and it's the value of the fish that's making the other fish that is plugged into that escaped spawner.

Here's an escaped spawner who hasn't done his thing yet. Somebody comes along and pitchforks it; all of a sudden its value goes to nil.

Another enhancement technique is to enforce poaching laws.

Those are average values for the Columbia-Snake River system. The values were not computed for individual sub-basins.

We've got certain stocks that reproduce themselves much more efficiently than other stocks. For example, down-river stocks reproduce themselves most successfully in terms of escaped adults, or adults to the fishery. They don't have all these dams to go through and get spun around and chopped up in the turbines. If you were to carry the argument to its logical conclusion, one would say the down-river fish are much more valuable than up-river fish and many up-river fish are close to worthless, because all they can do is replace themselves with no harvest.

Now you're in a real bad political situation. That means Idaho gets no attention at all. So, we have stopped short of assigning values based on individual areas and individual stocks, simply because as soon as a politician gets a hold of that, all the money goes to the Willamette, nothing gets spent up-river. It gets real complicated.

Economists have to be a little bit careful on how they do things. They have to consider the audience, and the use to which their figures are going to be put.

(Buell): In our programs there's a use, a reason for computing values, and that is to make decisions. I don't personally believe the decisions ought to be made solely on the basis of economics as much as politicans and administrators would like them to do so.

(Paul Kopas): Economic efficiency is only one of the considerations that we're going to take into account. Some of those other considerations can be in conflict. For example, one of the accounts in SEP's five account system is native involvement. We have a native political issue.

That's the sort of decision, or the types of objectives that a politician is going to have to face. As an economist, I'm not going to start monkeying with the figures. If I were to say to you that you should tell somebody that the egg to adult survival rate for chinook in the upper Snake River is 90 percent, because that's going to make your studies look better, would you do that?

(Buell): I wasn't suggesting that economists should do that. It's not the message that I intend to put across.

(Kopas): What I'm saying is that we have to analyze consistently and correctly. I say correctly in the sense that we've got to do it in a way that is going to mean something in economic terms, not mean something in political terms. If people want to express things in political terms, that's what they should do.

(Chamberlain): What do you think of the $550?

(Kopas): I don't have any difficulty with the explanation that you gave, and I could give you a bunch of jargon to say that that is the economically legitimate way of going about it.

(Ross Peterson): The last couple of days I've heard a lot of agreement that some form of evaluation has got to be done. I'm interested in knowing from both the Americans here and Canadians, whether or not the cost of evaluation and monitoring is built into the benefit/cost analysis, and if not, why not?

(Buell): In some cases it is, and in some cases it's not.

(Al Lill, SEP, Vancouver): In SEP, it's an overhead cost that's built in. One thing that should be pointed out is that when you're looking at these $550 figures, or any other kind of figures, you have to consider what discount rates are used.

The discount rate has a tremendous effect on fisheries benefit/cost ratios because of the usual long-time payoffs.

For example, the fish, say five years from now, at a ten percent rate, it might cost you a dollar. It's actually only worth about 60 cents in today's terms. If you use a five percent rate, it might be worth over 80 cents, or something like that. There's a tremendous variation depending on the kinds of standard you have to use. We're dictated to by our Treasury Board to use a ten percent discount rate; that has an enormous impact on your benefit/cost ratio.

(Buell): I think BPA is using three percent at this time. So, some of these 12 to 1 and 6 to 1 benefit/cost ratios are using three percent discount rates.

WORKSHOP CLOSING REMARKS

J. H. Patterson
Habitat Management Division, DFO
Delbert G. Skeesick
USDA Forest Service
Willamette National Forest

(Patterson): I'd like to summarize a few of the key points and the common themes from the various participants.

Some of the common themes heard in the last two-and-a-half days are: fish habitat inventory is required for various management needs, the need to identify and understand functional components of habitat that are important to fish production, and specific requirements in inventory, restoration and enhancement opportunities.

It was pointed out that hard data are lacking in some areas, particularly on estuarine habitat information and the water quality criteria needed in evaluating water quality components of restoration projects.

Research is essential; monitoring, assessment and evaluation, are equally important. As Carey McAllister said, let's not just develop the project prescriptions in a cooperative sense, and then go back to our respective tents and consider the job done. There is a short and long-term follow-up process required for evaluating the effectiveness of our management prescriptions. We must learn from our failures, as well as our successes.

It is essential to integrate all the components in our department. We have Stock Management, Habitat Management, and the Salmonid Enhancement Program, and our Fisheries Research Branch, all of which are often separated in the heirarchy, but have to be integrated in developing restoration plans at the watershed level.

There are constraints that we have to operate under, for example, the continuing reduction in people resources and funding to do the job. We have to become more cost effective in dealing with these projects and cooperative use of government and non-government funding is essential.

We heard Jim Van Tine and Gary Logan express a common theme and dilemma in DFO -- the need to act now with the information and resources available, as opposed to waiting for the absolute answer. Gordon Hartman encouraged us to take the realistic course -- a parallel approach with results from research and evaluation projects being conveyed to the operational staff promptly. Del Skeesick will mention one way project and program information can be easily conveyed to a broad audience.

Communication is often a constraining factor in integrating all those components. Coordination of the diverse departmental activities and integrating the program with our provincial colleagues, is required.

Some other considerations, as pointed out by Dave Bustard, are the differences between the coastal and the interior freshwater habitats, and that we may not be able to make broad applications of results or techniques across the province. In addition, the implications of restoration activities to the stream are often ignored. The hydrological considerations of putting in enhancement structures perhaps will negate any benefits that we hope to accrue. Projects must be considered on a basin-wide context with input from hydrologists, engineers and biologists.

We must do our job now and maximize our efforts and resources. All speakers emphasized cooperation, communication and integration, within the department level, between research and operational levels, and between government agencies. I would add to this our intention to develop cooperative programs with non-government organizations such as Ducks Unlimited.

In B.C., the Department of Fisheries and Oceans is attempting to incorporate all those essential components through integrating all the major groups within our department. We have a restoration development committee which coordinates the habitat restoration activities for the Region, which include habitat management, SEP and research components.

As Al Lill pointed out, he would like to see us continue our interaction with the Salmonid Enhancement Program. This is certainly something that I intend to pursue. In a broader sense, Gordon Hartman, and many of the other speakers, pointed out a need to take this departmental integration to the area planning committees, in an attempt to get our act together internally. Then, when we interact with the provincial and private sector in the cooperative resource management plans, in watershed or basin-wide systems, we will know the bottom line as far as our resource is concerned, when going to the negotiating table with other land and water managers and users.

(Skeesick): I believe sincerely that habitat enhancement is not just a buzzword that will disappear in the next year or two, or even five.

I think we are seeing, as populations develop, and our communities develop, that there is always going to be a tremendous need for habitat development and enhancement. Certainly, we are just scratching the surface as far as the technology is concerned.

Your SEP in B.C. and our STEP in Oregon are enjoying a great deal of public interest, because people really do like fish. People really love them, and they really want to see good things happen. So, I think we need to make every effort to publicize what we are doing, individually, or our agencies. We also need to continually publicize to those folks what they can do also. Certainly, they can do much in the area of breaking down the institutional restrictions that we might have.

We really need to sell programs, and I think we've got a golden opportunity. I think people find biologists entertaining; we need to get out and entertain the public, as well as instruct them.

One thought that comes to my mind that would certainly go a long ways towards keeping everybody informed, is a publication of The American Fisheries Society called "Fisheries." The intent when "Fisheries" was planned was that it was to be able to communicate this very kind of information on a very regular basis. Everyone of our agencies, at regular intervals, should write articles for "Fisheries", not necessarily telling exactly what was accomplished, but more in the vein of what is being done.

Certainly, there is additional need to continue the momentum that this workshop has developed.

There could be opportunities in the international chapter of Pacific Fisheries Biologists, to flock back and forth between British Columbia and Washington. You could keep a continuing flow of discussions about the whole concept of habitat development and enhancement.

Several years ago, I had an opportunity to exchange information with a wonderful Canadian, Cam Stevenson, who I regret is now dead. I was so impressed with him, I so enjoyed his different approach from what we did down in the States. That was when he was president of The American Fisheries Society.

From those discussions came the whole concept of the "North American Journal of Fisheries Management." At that time, many of us were criticizing the transactions. We were criticizing the journal of The Fisheries Research Board of Canada, because the level of documentation and the level of scientific input needed for an article didn't allow for inclusion of a monitoring type study, or a study that was less scientifically rigorous.

That really was the genesis for the publication of the "Journal of Fisheries Management." That is a perfect publication for reporting the results of habitat enhancement activities. We should encourage each other to get our monitoring work done, and demonstrate the fact that these projects are efficient, economic, and then get them into a publication.

APPENDIX 1

Participants in the Habitat Improvements Workshop
Whistler, B.C., Canada
May 8-10, 1984

[Each participant's title and place of employment is that which was current at time of publication.]

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APPENDIX 2

Original Agenda for Workshop

Fisheries and Oceans Canada

Habitat Improvement Workshop

May 8-10, 1984

Delta Mountain Inn

Whistler, B.C., Canada

Organized by:

Habitat Management Division
and
Salmonid Enhancement Program

Contact:

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AGENDA
HABITAT IMPROVEMENTS WORKSHOP
DEPARTMENT OF FISHERIES AND OCEANS, CANADA
MAY 8-10, 1984 - Whistler, B.C.

May 7 Monday

1600	Arrival at Delta Mountain Inn Whistler, B.C.

May 8 Tuesday

0800	Welcome: agenda announcements instructions	J. Patterson
0810	Introductory/Background Remarks	T. Bird
0820	Session I **Estuarine and Marine Habitat Improvements**	**Chairman:** **C. Levings**
0840	Water Quality - The Forgotten Restoration Issue	M. Nassichuk
0910	Campbell River Estuary Restoration and Creation	M. Brownlee
0940	Fish and Invertebrate Utilization of Campbell River Estuary Islets	C. Levings
1010	**COFFEE**	
1030	Small Estuarine Development and Restructuring	G. Ennis
1100	Nanaimo Estuary Log Storage Area - Estuarine Restoration	C. McAllister
1130	Questions and Discussion	C. Levings
1200	**LUNCH**	

1330	**Session II** **Lake Habitat Improvements**	**Chairman:** **A. Tautz**
1345	Lake Enrichment	K. Hyatt
1415	Coho Colonization of Inaccessible Headwater Habitats in the Quinsam River Watershed	J. Van Tine
1515	**COFFEE**	
1530	Enhancement of Kokanee Shore Spawning Sites in Okanagan Lake, B.C.	B. Harris
1600	Establishment of Plant Communities Along Reservoir Shorelines	D. Skeesick
1630	Question and Discussion Period	A. Tautz
1730	No Host Bar	

May 9 Wednesday

0800	**Session III** **Improving Small Stream Habitats**	**Chairman:** **J. Buell**
0815	Salmonid Habitats - Improvement Strategies from the Carnation Creek Study	G. Hartman & C. Scrivener
0845	Rehabilitating Spawning and Rearing Habitat in a Destabilized Stream by Placing Gabion Weirs	H. Klassen
0915	Instream Habitat Improvements	G. Taylor
0945	**COFFEE**	
1000	Instream Pits and Side Channel Development	D. Marshall
1030	Stream Morphology and Enrichment	H. Mundie
1100	Stream Restoration in the Lower Mainland, B.C.	B. Dane
1130	Some Differences Between Coastal and Interior Stream Ecosystems and the Implications to Fish Production	D. Bustard

1200	**LUNCH**	
1330	Fish Creek Enhancement Project and Monitoring Study	D. Heller
1400	Questions and Discussion	J. Buell
1430	**Session IV** **River Habitat Improvements**	**Chairman:** **A. Lill**
1445	**COFFEE**	
1500	Some Observations and Thoughts Concerning Gravel-bed Rivers	D. Hay
1530	Major River Diversions - Elk River	A. Wood & B. Lister
1600	Stream Enhancement in the Oregon Coast Range	R. House
1630	Questions and Discussion	A. Lill

EVENING

2000	Washington State Salmon Habitat Enhancement Program	L. Cowan & D. King
2030	Campbell River Estuary Restoration Film	M. Brownlee

May 10 Thursday

0800	**Session V** **Watershed Improvements**	**Chairman:** **G. Logan**
0815	Riparian Rehabilitation and Habitat Monitoring	E. Claire
0845	Placer Tailings Reclamation and Habitat Restoration	J. Andrews
0915	Fisheries Rehabilitation on Agricultural Land in Ontario	R. Biette
0945	**COFFEE**	

1000	False Creek - B.C. Place Development - Past and Future Perspectives	R. Waters
1030	Institutional Frameworks for Habitat Improvement Implementation - Salmon River	R. Peterson
1100	Economic Evaluation Issues	P. Kopas
1130	Questions and Discussion	G. Logan
1150	Wrap-up	J. Patterson